SOCIETÀ ITALIANA
DI ECONOMIA
AGRO-ALIMENTARE

ECONOMIA AGRO-ALIMENTARE *FOOD ECONOMY*

An International Journal on Agricultural and Food Systems

2021, Vol. 23, Issue 3

FrancoAngeli
OPEN ACCESS

SIEA
SOCIETÀ ITALIANA DI
ECONOMIA AGRO-ALIMENTARE

ECONOMIA
AGRO-ALIMENTARE
Food Economy

(Rivista fondata da Fausto Cantarelli)

FrancoAngeli

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Economia agro-alimentare/Food Economy is a triannual peer-reviewed scientific journal published by FrancoAngeli Edizioni on behalf of the Italian Society of Agri-food Economics (SIEA), founded in 1996 by the then President of SIEA Fausto Cantarelli. It offers an international forum for the discussion and analysis of mono and interdisciplinary socio-economic, political, legal and technical issues, related to agricultural and food systems. It welcomes submissions of original papers focusing on agriculture, agribusiness, food, safety, nutrition and health, sustainability and environment, including all processes and infrastructure involved in providing food to populations; as well as the processes, inputs and outputs involved in consumption and disposal of food and food-related items. Analyses also include social, political, economic and environmental contexts and human resource challenges. Submissions should be addressed to an international audience of researchers, practitioners, and policy makers, and they may consider local, national, or global scale. The decision to publish the article, at the end of the process of evaluation and review, is the prerogative and responsibility of the Editor-in-Chief. The articles published are under the total responsibility of Authors.

Amministrazione: v.le Monza 106 - 20127 Milano - Tel. 02/2837141 - Fax abbonamenti 02/26141958 - e-mail: riviste@francoangeli.it

Registrazione del Tribunale di Reggio Emilia n. 932 del 6 novembre 1996 - Direttore Responsabile: dr. Stefano Angeli - Quadrimestrale.
 Stampa: Logo srl, sede legale: Via Marco Polo 8, 35010 Borgoricco (Pd).

III quadrimestre 2021 - Finito di stampare nel mese di dicembre 2021

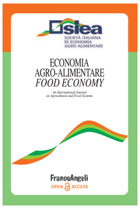
Economia agro-alimentare
Food Economy
2021, Vol. 23, Issue 3

Sommario

Economia agro-alimentare /
Food Economy

An International Journal on Agricultural and Food Systems

Vol. 23, Iss. 3, Art. 1, pp. 1-5 - ISSN 1126-1668 - ISSNe 1972-4802
DOI: 10.3280/ecag3-2021oa12832



Guest Editorial
Current use and new perspectives for the Farm Accountancy Data Network

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FADN in the EU and Italy

More than 50 years after its establishment, the European Commission is planning a major revision of the Farm Accountancy Data Network-FADN, adapting its information set to user needs to analyse the impacts of Agricultural and Rural Development policies on new challenges. Agriculture and the related sectoral policies have changed in recent decades and are now subject to a new radical change soon, mainly in the environmental issues, development of rural areas and valorisation of public goods.

Accordingly, the recently approved "Farm to Fork" EU Strategy includes ambitious proposals for a revision of the Farm Accountancy Data Network Regulation to transform it into a "Farm Sustainability Data Network"-FSDN, aimed at contributing to a wide uptake of sustainable farming practices and the related and necessary data collection and analysis.

The process of integrating environmental themes and objectives into the CAP and the adoption of the European model of multifunctional agriculture started in the 90s have been consolidating over time. At the same time, the importance of the monitoring and evaluation activities of the CAP has grown, giving a strong relevance to the quantification of policy objectives and the policy evaluation process. In this context, the role of the FADN, as the only source of harmonised microeconomic farm-level data in the EU, is confirmed and reinforced.

In the meanwhile, the improvement of the analytical and political relevance of FADN, with the addition of environmental and social dimensions of sustainability, has already started in the Italian FADN, and many of the relevant information and variables are already included in the Italian FADN dataset. Presidential Decree 1708/65 entrusted the National Institute of Agricultural Economics (INEA) with the coordination of the FADN Survey in Italy, designating it as the liaison body between the Italy and the European Commission. In 2015, INEA was incorporated into the Council for Agricultural Research and Economics (CREA), taking over the tasks and functions previously attributed to INEA, including its role as FADN liaison body.

Another important point, both for the national and EU FADN systems, is the strong need to minimise the response burden for survey participants and contribute to the more general objective of reducing administrative burdens, not only to the FADN Survey but also to the entire EU agricultural statistics system. This important goal can be achieved by improving connections, links, and exchange of primary data with existing data collections, ensuring a strong complementarity to produce harmonised statistics. Data should be collected once and re-used many times afterwards (Collect Once, Use Many Times). This "new" approach allows an improvement in efficiency by reducing the effort that researchers, data collectors and farmers make to collect, process, and use data. Only data, variables, and information not available in other data sets should be collected in the field. In this perspective, the Italian FADN has formalised agreements with several public institutions (I.e. the subsidies payment agency-AGEA and the National Institute of Statistics-ISTAT) and private companies that manage the farmers' logbook for the exchange of statistical, administrative and managerial information.

Why a special issue on FADN

In order to respond to the above-mentioned challenges, the National Council for Agricultural Research and Economics (CREA) - Research Centre for Agricultural Policies and Bioeconomy, which coordinates, manages and enhances the Italian FADN, in collaboration with the journal *Food Economy*, has launched a call for paper for a special issue of the review on the theme "Current use and new perspectives for the Farm Accountancy Data Network". This special issue wishes to offer to researchers, scholars, technicians and advisors the opportunity to discuss and provide important insights into the current uses and possible evolution of FADN survey in Italy, EU and neighbour or pre-accession Countries, highlighting its potential future developments and, where appropriate, critical points.

The call was launched in March 2021, and the number of contributions submitted, the variety and quality of the topics addressed demonstrate how the availability of up-to-date, reliable and broad-spectrum data is fundamental to provide the knowledge base useful to design, implement, monitor, and evaluate relevant policies, especially the Common Agricultural Policy (CAP), including Rural Development measures. On the other hand, FADN is also fundamental for the evaluation of EU policies focusing on the environment, adaptation to climate change, land use changes, and achievement of Sustainable Development Goals (SDGs).

The topics addressed by the submitted contributions range from the integration of the FADN with the system of agricultural statistics and administrative databases, to the more traditional microeconomic analyses related to the technical and economic management of farms, up to several examples of use of FADN data in the context of evaluations of agricultural and rural development policies in Italy and abroad. There are also contributions that propose innovative methodological approaches in the use of economic, accounting, and structural data of the FADN.

The quantity and the quality of submitted contributions have been very high. The papers accepted for publication, after an independent double-blind peer review, according to the rules of the journal, can be classified in three homogeneous thematic areas: Evaluation of policies, Methodology for the analysis and use of data, Farm-level analysis. A summary is given in the table below.

Evaluation of policies	• The use of FADN methodology to support the evaluation of business development plans in the RDP Sicily 2014-2020
	• Ten years later: diffusion, criticism and potential improvements in the use of FADN for Rural Development assessment in Italy
	• Enhancing the Italian FADN for sustainability assessment: state of the art and perspectives
	• Estimation of the impact of CAP subsidies as environmental variables on Romanian farms
Methodology for the analysis and use of data	• Generating cropping schemes from FADN data at the farm and territorial scale
	• FADN data to support policymaking: the potential of an additional survey – Federica
	• Modeling change in the ratio of water irrigation costs to farm incomes under various scenarios with integrated FADN and administrative data
	• Mapping data granularity: the case of FADN
	• Use and users of FADN data in Italy

Farm-level analysis	• Financial sustainability in Italian Organic Farms: an analysis of the FADN Sample
	• Sustainability and competitiveness in farms: evidence from the Lazio region agriculture through FADN data analysis
	• Economic characterisation of irrigated and livestock farms in the Po River Basin District
	• Organic and conventional farms in the Basilicata region: a comparison of structural and economic variables using FADN data
	• Investments financing at farm level: a regional assessment using FADN data
	• The Role of Neighborhood Effects on Investing Dairy Farms
	• The impact of irrigation on agricultural productivity: the case of FADN farms in Veneto

In recent years, the steering committee and the staff of the Italian FADN have actively worked on the reorganisation and optimisation of the survey, focusing on the achievement of a greater connection between the different data sources and providers.

In Italy, the experience of conducting the FADN Survey in a coordinated way with the Economic Accounts for Agriculture Survey (EAA), performed by Istat, is an example of streamlining the agricultural statistics system, with a more efficient data collection process, in line with the EU Commission's guidelines for the creation of an Integrated Farm Statistics (IFS).

Moreover, the Agreement for a strengthened cooperation and data exchange, signed in 2017 by CREA, Italian Ministry of Agricultural and the Payment Agency in Agriculture and Rural Development (AGEA), aims at exchanging data and methodologies for the joint achievement of their institutional tasks in the field of economic.

Recently, the Italian FADN has started up several working groups, some of which are specifically addressed at updating the current information set of the FADN survey in Italy, focusing on adapting the accounting network to the needs of the next programming period of the Structural Funds. Working groups have also actively investigated the possible ways to improve data exchange with existing information systems, including the administrative ones.

The contributions included in this Special Issue demonstrate the extent of the use of FADN in the policy evaluation process and technical assistance to the Ministry of Agriculture and Regional Administrations in the design, simulation, and analysis of new agricultural policies and rural development measures. Furthermore, many articles focused on widening the use of FADN data for the evaluations of environmental performances of farms.

However, the use of FADN data and information remains dominant for analysing the competitiveness of farms according to the different farm typologies, location, production sectors and level of sustainability of the production processes, which is considered by most of the articles submitted.

A further aspect covered by the selected articles concerns methodological issues related to the possibility of exploiting the information potential of the survey by carrying out pilot surveys with the collection of farm variables not available in the "standard" FADN survey, and enlarging the FADN sample with a specific (ad hoc) sub-sample of farms adopting specific agricultural policy measures, or, finally, with the hints and suggestions for the integration of FADN dataset with administrative data.

As Guest editors, we are aware that the topics addressed in this issue cannot be considered exhaustive of the wide panorama of uses and developments of the FADN data. However, the selected articles highlighted the most relevant issues for the future development of the FADN dataset, with the aim to respond to the needs of evaluation of the agricultural policies and to create reports, thematic insights, scientific studies and analyses.

Thus, we would like to thank all the authors: their valuable contribution made possible to publish an interesting and comprehensive review of the use and perspectives of FADN. It will serve as a basis for further analysis and studies on the future development of FADN to a Farm Sustainability Data Network.

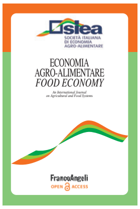
We are also grateful to the reviewers for their important support to the authors in improving their article; without them, the finalisation of this special issue would have been impossible. Many thanks also go to the editor-in-chief of the journal Maurizio Canavari, to the Associate Editors Sedef Akgungor, Valeria Borsellino, Alessio Cavicchi, Catherine Chan-Halbrendt, Alessio Ishizaka, Simona Naspetti, Soren Marcus Pedersen, Stefanella Stranieri, and to the Editorial Assistant Alessandro Palmieri for their support throughout the presentation and publication process.

Available online: 12/01/2022

Economia agro-alimentare /
Food Economy

An International Journal on Agricultural and Food Systems

Vol. 23, Iss. 3, Art. 2, pp. 1-26 - ISSN 1126-1668 - ISSNe 1972-4802
DOI: 10.3280/ecag2021oa13149



The use of FADN methodology to support the evaluation of business development plans in the RDP Sicily 2014-2020

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Abstract

Article 19(4) of Regulation (EU) No 1305/2013 provides that business start-up aid for young farmers, non-agricultural activities in rural areas and the development of small farms shall be conditional on the submission of a business plan. Therefore, this tool, also known as Farm Development Plan (FDP), is mandatory to verify the economic improvement of an investment under sub-measures 6.1 "Business start up aid for young farmers", 4.1 "Investments in agricultural holdings" and operation 6.4.a "Investments in creation and development of non-agricultural activities" so that rural development resources can be directed towards those project ideas which are consistent with the objectives and purposes of the rural development strategy and, thanks to the support, have the highest probability of success. The article presents the lesson learned from the Sicilian experience of designing a web-based tool for FDP submission, namely "PSAWeb Sicilia". This device allowed the Managing Authority (MA) of RDP Sicily 2014-2020 to make available an FDP scheme to users in compliance with EU obligations, consistent with the objectives and purposes of the Programme, as well as with the implementing and procedural provisions of regional calls. The computerised management of the FDPs ensured better coordination between the offices responsible for verifying and evaluating the proposals,

Article info

Type:
Article
Submitted:
15/05/2021
Accepted:
20/09/20211
Available online:
12/01/2022

JEL codes:
O13, Q18

Keywords:
Rural Development Programme
Business plan
Investments
FADN

Managing Editor:
Lucia Briamonte,
Luca Cesaro,
Alfonso Scardera

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while processing and analysis of aggregated data from over 8,400 business plans provided an in-depth knowledge of the investment needs in Sicilian agriculture and a better capacity to forecast the RDP potential response as well as some aspects of specific interest to the regional agricultural system. Thanks to PSAWeb Sicilia, in fact, a large amount of data at farm, sectoral, territorial and type of investment level was collected providing information of inestimable value not available from other data sources. The assessment of access requirements in terms of farms' economic size, economic-financial viability and profitability was ensured by borrowing principles and procedures from the Italian FADN. The cooperation between the MA and CREA-PB achieved several results. Firstly, the data collected combined with the monitoring data have been made available for the evaluation activity and for the communication to the public of the RDP implementation. This information will also be very useful both for better targeting interventions in 2021-22 and for reprogramming them in the future CAP. Finally, as a positive externality, the use of the application has contributed to increasing accounting knowledge among operators and technicians in the agricultural sector, so that it has become a teaching tool in some university courses.

Introduction

In 2016 CREA-PB and the Managing Authority (MA) of RDP Sicily 2014-2020 started a collaboration for the design and development of PSAWeb Sicilia, an easy-to-use application made available to potential beneficiaries of some investment measures to draw up, in compliance with EU obligations, the farm development plan.

The experience gained with the devices adopted by the MA in the previous programming periods did not allow to adequately assess the projects due to shortcomings in the detection of income and profitability indicators of the recipient farms, necessary to support an accurate assessment of the economic and financial viability of projects; furthermore, the lack of attention paid to the assessment of the needs and objectives of the intervention did not allow to properly direct the support towards the projects more consistent with the results and the expected impacts of the measures (Agriconsulting, 2017; European Court of Auditors, 2017).

Having data available for monitoring and evaluation, to improve programme management, and to communicate results without burdening regional offices was a clear need that emerged during the 2007-2013 programming period (Agriconsulting, 2017). As part of the obligations of the ex-ante conditionality of the Programme, with the launch of the RDP Sicily 2014-2020, the same regional offices were also called upon to organise the production and gathering of data to be made available to the evaluators along with the information provided by the monitoring system (Article 76 of Regulation (EU) No. 1305/2013).

PSAWeb Sicilia was therefore designed and developed to clearly and accurately represent the structural characteristics of farms, the sectors of intervention, the investment plan and its purposes, consistent with the objectives of the RDP as well as with the constraints imposed by the call and by the implementing provisions of the sub-measures/operations.

In addition to ensuring a better capacity of the Regional Administration to verify the eligibility conditions set out in the calls, a rigorous assessment of the economic and financial viability of the project proposals is provided by the connection between PSAWeb Sicilia with the web application "Bilancio semplificato RICA" (BS), that is a simplified form of the Italian FADN accounting software (GAIA). In fact, in accordance with official accounting criteria, BS allows the preparation of a complete financial report (balance sheet, income, profit and loss and equity statements), both for ex-ante and ex-post investment situation, and the calculation of the economic and social indicators chosen by the regional Administration.

The application was also designed and developed to ensure a better ability to verify and evaluate the priority requirements set by the Programme with the selection criteria as well as to measure the project's contribution to the achievement of the Focus Area target which sub-measures are related to.

The computerised management and the collection in a single database of over 8,400 Farm Development Plans (FDP), acquired up to January 2021 and related to the calls for sub-measures 4.1, 6.1 and operation 6.4.a, have allowed to the different regional branch offices responsible for the verification and evaluation of the FDPs both to access easily to data and to reach their full operational capability in order to make the management of the administrative processes more efficient in handling the appraisal of applications.

The collection of a wide range of data, given the number of observations and the level of detail, led to build a large dataset whose variety of information is not available from official statistical sources. The processing and analysis of this data has resulted in the production of statistics, thematic maps, reports made available for the evaluation of the Programme performance, together with the monitoring data, as well as to support the reprogramming of the interventions for the calls to be put out until 2022, and to build the rural development strategy in the future CAP.

No less important was also the role of PSAWeb Sicilia and its connection to the web-based financial application system (BS) in spreading the accounting knowledge among operators and technicians involved in preparing the FDPs to apply to RDP calls. Moreover, University of Catania and other higher technical schools in the same Province showed great interest to use it for didactic purposes.

The paper, after exposing the context in which the activity was carried out and the methodological aspects underlying the design of the application, describes the advantages and results achieved thanks to its use. Finally, the paper concludes with an analysis of the medium-term perspectives and possible evolutions of the use of PSAWeb Sicilia.

1. Background

According to the provisions of the Commission Implementing Regulation (EU) 808/2014, the MA is required to make available to companies a FDP scheme for investment measures which, through the clear and detailed representation of the project idea, the characteristics of the farm, the timings and objectives to be achieved by the investment plan, allows the evaluation of the economic and financial viability of the project and the consistency with the objectives and results expected from the measure.

The experience gained with the use of the tools adopted by the MA in the previous programming periods (MS Excel sheet in the ROP Sicily 2000-2006, MS Access investment business plan (PAI) in the RDP Sicily 2007-2013) did not allow to adequately support the Administration in selecting the projects with the greatest chance of success and which best reflected the priorities defined by the Programme (Agriconsulting, 2017). The same limitations were pointed out by a study of the European Court of Auditors that investigated the role of the EU in supporting young farmers and promoting generational renewal. The study, conducted in the four Member States with the most relevant spending for the support of young farmers, France, Spain, Poland and Italy, found that in the regional case studies examined, including Sicily, support for generational renewal was based on an inadequately defined intervention logic, which did not ensure targeted support (European Court of Auditors, 2017). Moreover, it has been brought to the attention that insufficient data on the income and profitability of recipient farms, useful for better targeting support, were not collected and that lack of attention was paid to the assessment of the needs and objectives of the intervention since the expected results and impacts were not accurately recorded.

The recommendations of the Court of Auditors addressed to the Commission and the Member States underlined the importance of promoting generational renewal by applying selection methods that prioritise interventions in favour of more qualified young farmers and less favoured areas, that is what was done in the current programming period, and by implementing tools, such as business plans, so that it is possible to "prioritise beneficiaries likely to increase the viability of their holdings thanks to the aid" (European Court of Auditors, 2017). The business plans examined in the case studies were found to be of variable quality and their goals were often poorly designed. Moreover, with a view to improving the monitoring and evaluation framework, it was also recommended to draw on best practices EU Member States in their monitoring systems and evaluation reports. In this regard, the experience of Emilia Romagna was reported which, in the ex-post evaluation of the 2007-2013 RDP, used the data of the FADN to carry out a counterfactual analysis, among a sample of young farmers beneficiaries of measure 112 and two samples of farmers, reclassified by age. This analysis was based on elements such as standard production, gross value added, number of work units, farm size, labour productivity and land productivity.

Along with the need to improve the capacity for evaluating the projects, the ex-post evaluation of the 2007-2013 programming period also revealed the need for a better supervision action, functional to the monitoring and evaluation needs of the Programme, both in-itinere and ex-post, and to the communication of its results. In the face of greater flexibility and adaptability to changing monitoring needs, however, the need not to burden the already onerous management by the regional offices involved in the implementation of the RDP was stressed (Agriconsulting, 2017). These are the same regional offices that, in order to comply the ex-ante conditionalities of the RDP Sicily 2014-2020, were also called to guarantee the existence of a statistical information system to undertake evaluations to assess the effectiveness and impact of the Programme (Annex XI of the (EU) Regulation 1303/2013) and to organise the production and gathering of data to be made available to the evaluators along with the information provided by the monitoring system (Article 76 of Regulation (EU) No. 1305/2013).

Monitoring and evaluation activities, aimed to assess the impact, effectiveness, efficiency and relevance of the interventions and to contribute to better targeted support for rural development (art. 68 Reg. (EU) no. 1305/2013), are based on a series of qualitative and quantitative data on the progress and achievements of rural development policy. In order to overcome the critical issues encountered in this area during the previous programming period and to meet the various needs of knowledge, in 2016 the MA of RDP Sicily 2014-2020 and CREA-PB started a collaborative activity aimed to improve and make the Programme implementation more effective with particular reference to the management procedures of some investment measures and the need of knowledge of some specific aspects of their implementation. Right from the start it was found that most of the needs of knowledge and critical aspects outlined above are linked by the business plan which, in addition to meeting specific regulatory constraints, has shown that it can represent, if accompanied by suitable tools and procedures, a valuable source of information of strategic importance for planning and monitoring activities. An example of this kind is the first experimentation, carried out by CREA-PB, related to the design of a tool for the evaluation of the business plans required for the application to "young farmers package" (sub-measure 6.1.1 in combination with sub-measure 4.1.1) of the RDP Abruzzo 2014-2020. "PSAWeb Sicilia" design and development were inspired by this experience and they were conceived within the Italian FADN project. This is another element of the various software applications and services that CREA-PB has developed to implement the accounting survey and to offer tools to support the business management of farms with the main objective of disseminating the vast information assets of the FADN and enhancing the experience gained in over fifty years of managing the FADN in Italy.

In fact, as the Italian Liaison Agency for the European FADN, pursuant to Regulation No 79/65/ECC setting up a network for the collection of accountancy data on the incomes and business operation of agricultural holdings in the European Economic Community, CREA-PB has as its primary objective the collection of structural and accountancy data of farms to satisfy the information needs of the European Union for the definition and evaluation of the Community Agricultural Policy. To this end, CREA-PB has developed, in line with the provisions of the abovementioned regulation, its own accounting methodology which has resulted in a double-entry management accounting software (GAIA) which allows, even to those who do not possess specific accounting knowledge, to collect, classify, determinate, control and analyse the facts pertinent to the management, both of those properly accounting and of those of an extra-accounting nature typical of the farm. GAIA, in fact, was designed not only for the collection of FADN data but also as a tool free of charge for farmers wishing to keep accounts according to a solid methodology that allows the analysis of the results obtained on the basis of common rules. One of the main characteristics of the Italian FADN accounting method is its compatibility with the rules laid down by specific EU legislation, with those of the statutory financial statements and the European system of national and regional accounts (ESA) as well as with international accounting standards (IAS/IFRS).

By virtue of the experience acquired with the FADN management in Italy, the knowledge and skills of researchers, technologists and programmer analysts, CREA-PB has conceived and implemented a series of web applications which, expanding the field of application of FADN methodology, were put at the service of farmers and advisors, whether they are involved in the FADN survey or external. A further objective of CREA-PB is precisely the promotion of bookkeeping in farms. In Italy, in fact, the use of the annual budget is not yet widespread among operators in the agricultural sector since the national tax legislation does not require sole proprietorship and simple partnership farms, i.e. most of the agricultural holdings in Italy, to keep accounts. Therefore, CREA-PB developed the web procedure "Bilancio Semplificato RICA" (BS) in order to minimise the amount of data required by FADN survey and to reach an increasingly wider audience of farms outside the FADN survey, without sacrificing the FADN accounting methodology rigor. Efforts have been focused successfully on making easier the phase of collecting technical and economic data, preparatory both to the definition of the economic situation, according to the FADN methodology accounting scheme, and to the assessment of the level of competitiveness of the farm. The BS therefore represents a decision support tool which allows to measure production results and to compare them with technical and economic average data, used as benchmarks, relating to homogeneous groups of farms (by geographical area, type of farming and economic size) from the Italian FADN database.

Furthermore, the aforementioned characteristics, its ease of use and usability through the web have made the BS a suitable tool for assessing the economic and financial viability of FDPs.

Starting from these assumptions, the connection between PSAWeb Sicilia and BS allowed to import into each FDP, in addition to the financial statement report prepared according to the income statement and balance sheet (ex ante and ex post situation), also specific economic and social indicators chosen by the regional administration to assess projects submitted under the various sub-measures/operations. The use of the BS has not been made mandatory for the FDP preparation but it has been given the faculty to present the financial statements in another form, as is the case with the official financial statements filed by the companies subject to the obligation according to the provisions of the national law. In any case, almost all users of PSAWeb Sicilia used the BS for the presentation of financial statements and this allowed the regional administration to have a considerable amount of computerised accounting data based on the same methodology and therefore homogeneous.

2. Materials and methods

The MA of the RDP Sicily 2014-2020 since November 2016 has adopted, for some investment measures, PSAWeb Sicilia which allowed the acquisition, storage and computerised management of 8,422 FDPs ensuring a better and more efficient implementation of the Programme and a significant support to knowledge for the evaluation and reprogramming of the interventions of some investment measures[1].

The analysis phase of the information needs that preceded the design of the device was aimed to:

- ensure the consistency and completeness of the data set necessary to evaluate the projects in a logic of complementarity with the information already contained in the application submitted to the Italian Paying Agency (AGEA);
- allow the collection of information not directly addressed to evaluate the single project as to provide an overall interpretation of the needs and characteristics of farms in the regional agricultural system, with particular reference to irrigation systems, employment, equipment, type of land tenure, characteristics of young farmers;
- get an overview of specific territorial aspects (Natura 2000 areas, less favoured areas, rural areas according to the National Strategic Plan) with aggregations at regional, provincial and municipal level.

PSAWeb Sicilia has been developed in four different versions according to the type of sub-measure/operation, ordinary or package, and the related eligibility requirements, selection criteria and type of eligible expenses.

The trial was started when the first sub-measure 4.1 call was published in 2016 and continued with the calls for sub-measure 6.1 (2017), operation 6.4.a (2017 and 2018) and sub-measure 4.1 (2020).

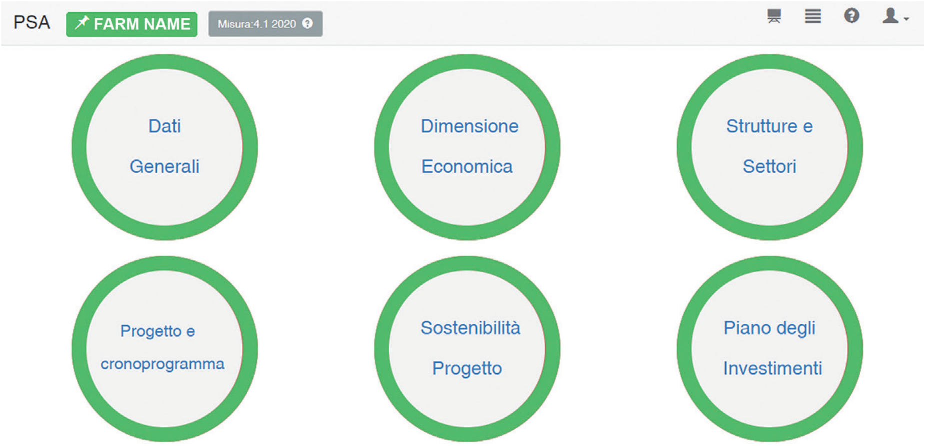
PSAWeb Sicilia, first of all, has responded to the Administration's need to make an FDP scheme available to users, in compliance with EU obligations (Reg (EU) 808/2014), consistent with the objectives and purposes of the Programme as well as with the implementing provisions and procedures of the regional calls.

Conceived as a standardised and modular tool (sub-measure/operation), PSAWeb Sicilia has generated a clear and accurate description of the structural elements of the farm, the sectors of intervention, the investment plan and its purposes.

Since the device has been specifically designed for the needs and characteristics of the RDP Sicily 2014-2020 and sub-measures/operations that require its use, it allows to capture all the relevant features by providing various innovative elements with respect to the methodologies and tools used in past programming periods.

1. Sub-measure 4.1 "Investments in agricultural holdings" (Calls, 2016, 2020); sub-measure 6.1 "Business start up aid for young farmers" (bando 2017); operation 6.4.a "Investments in the creation and development of non-agricultural activities" (call 2017, de minimis scheme, and call 2018, Agritourism - approved state-aid scheme.

Figure 1 - PSAWeb Sicilia - Dashboard



Source: PSAWeb Sicilia (http://psa.psrsicilia.it).

A specific function has been implemented to facilitate the verification of some calls' eligibility conditions, with particular reference to the minimum economic size to access to the aid. In fact, PSAWeb Sicilia provides the automatic typology classification (economic size and type of farming) of the farms, on the basis of the official standard output coefficients tables (Reg. (EC) No. 1242/2008) and the regional coefficients of agricultural products not covered by the official tables. This function represents an important innovation which, thanks to its automation, helps users to classify farms. In fact, the typology classification algorithm provides a number of exceptions that make the manual calculation somewhat difficult, exposing it to a rather high risk of error.

As shown in the previous paragraph, the connection with the BS application of CREA-PB (http://bilanciosemplificatorica.crea.gov.it) allows to generate the income statement and balance sheet, ex-ante and ex-post investment, according to a single methodology valid for all users, i.e. the official accounting criteria, ensuring relevance and homogeneity to the data processed by the Administration; this connection allows to calculate, and to import into the FDP, the economic and social indicators adopted for each sub-measure/operation to assess the improvement in the overall performance of farms and the economic viability of the projects (Table 1).

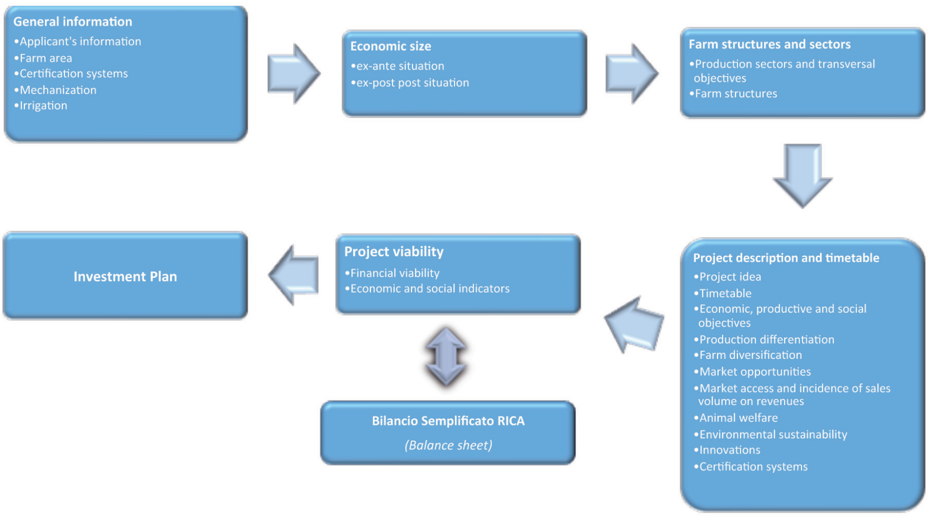
The preparation of guides to the FDP compilation, the organization of training sessions and seminars aimed to teach technicians how to use PSAWeb Sicilia and BS have supported users to submit FDPs.

Table 1 - Economic and social indicators by sub-measure/operation

Indicator description	**Sub-measures/operations**				
Economic indicators	**4.1 ***	**4.1 ****	**6.1**	**6.4.a de minimis**	**6.4.a State aid**
GSP/UAA (Gross land productivity)		X			
RC/TR (Incidence of direct costs)		X			
AV/UAA (Net land productivity)		X			
ROI = OI/KINV (Return on investment)	X	X	X		
TR/KFIX (Efficiency of fixed capital)	X	X	X		
VAt (Added value including non-characteristic revenues)	X	X	X		
R_OGA (profitability of other gainful activities)			X	X	X
RN (Farm profitability)			X	X	X
GSP (Gross saleable production)			X		
Social indicators					
AWU Annual work unit	X	X			
OI/FWU (Net profitability of family labour)	X	X	X		
VAt/AWU (Profitability of farm labour)	X	X	X		
Number of employees			X	X	X
Young males (< 40 years age)			X	X	X
Young females (< 40 anni di età)			X	X	X
Women			X	X	X
Disadvantaged people			X	X	X

* Call 4.1 2016; ** Call 4.1 2020.
Source: RDP Sicilia 2014-2020 Calls.

Figure 2 - Logical path of data entry in PSAWeb Sicilia



Source: CREA-PB.

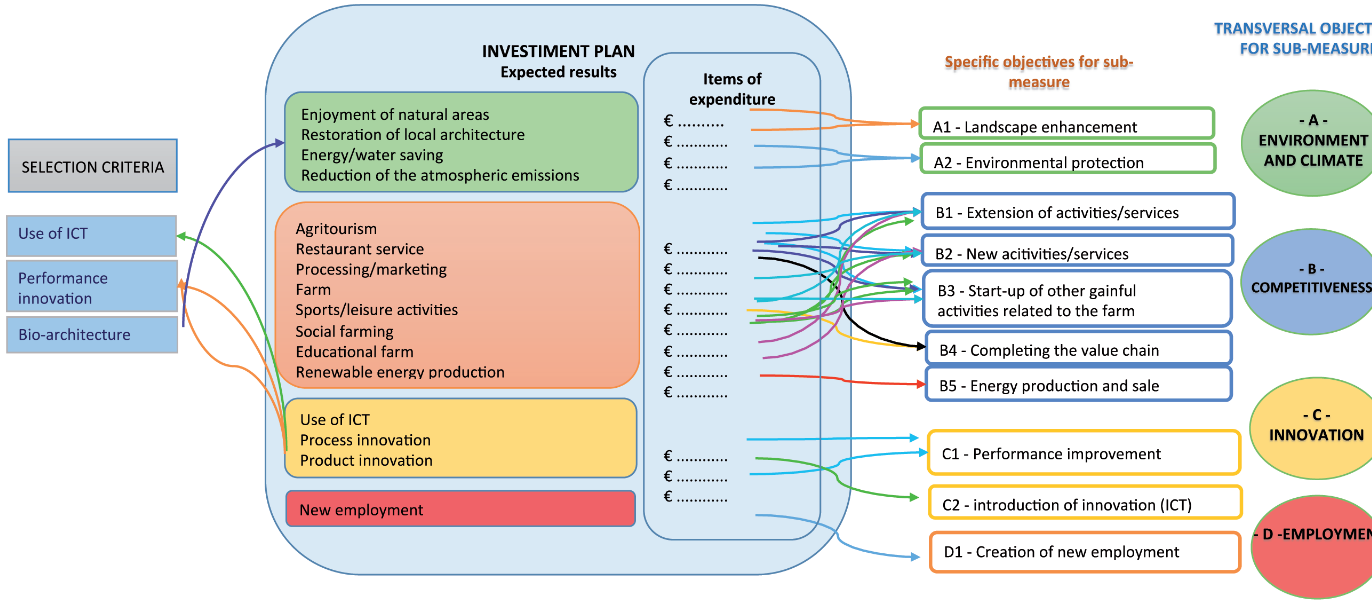
Another specific feature of the application concerns the methods to input the information related to the investment plan aiming to allow multiple levels of analysis. Specifically, the unique association of each expenditure item provided by the investment plan with the general measurement objectives and with the specific sub-measure/operation objectives (Figure 3) has made possible:

- the clear identification of the objectives set and the expected effects of the investment plan, in order to assess the coherence of the project with the purposes of the sub-measure/operation;
- the verification of expenditure parameters for the attribution of some scores related to selection criteria;
- the quantification of the contribution of the intervention(s) to the achievement of the expected results of the Focus Area to which the sub-measure/operation is related to.

The automated checks during the data entry phase, together with a series of tests to be carried out before delivery, as well as the printing of the various verification reports, have ensured a high level of consistency of the information stored in the database. In addition, the computerised delivery procedure was designed to prevent further changes and ensure the integrity and official nature of the data transmitted to the Administration.

Data acquisition was addressed to the collection of elements of particular interest for policy makers, with reference, for instance, to applicants, type

Figure 3 - Connection between the investment plan and transversal objectives, specific objectives and expected effects of sub-measure 6.4.a



Source: CREA-PB.

of land tenure, the physical farm size (Utilised Agricultural Area - UAA, Total Farm Area - TFA), UAA under NSP rural areas or less favoured areas, type of farming (TF), economic size (ES), labour, mechanisation, irrigation. Only a few of this data can be found on the Italian Informative Agricultural System (SIAN) but with several limitations to use and consult them in aggregate form and with this level of detail.

The following figure shows the main information stored in PSAWeb Sicilia Database by category.

3. Results

The experimentation of PSAWeb Sicilia application has broadened the scope of the "business plan". In addition to being a useful tool for farmers in guiding the development, modernization and competitiveness of their farms, it has also become a valid support for the MA, in assessing the consistency of the project idea with the objectives and purposes of the RDP. Moreover, it allows to verify the economic and financial viability of the project with particular attention to the income prospects of the recipient farms.

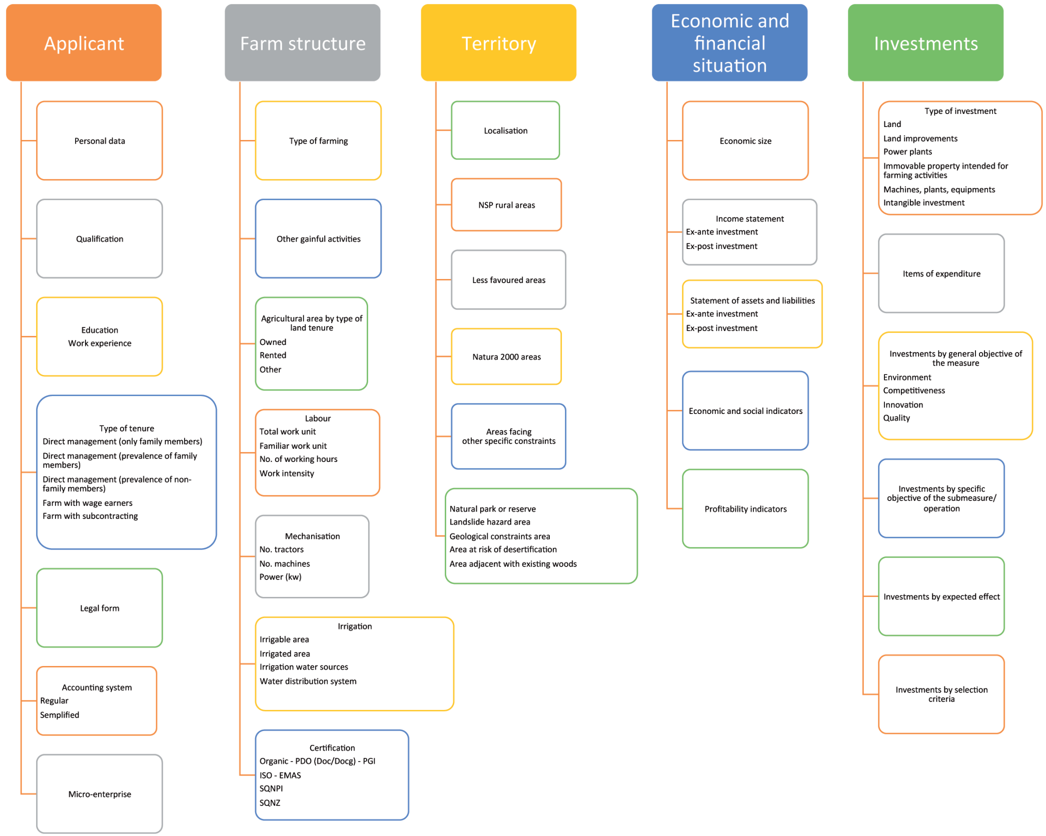
The MA, responsible for the implementation of the Programme which, for the programming period 2014-2020, is worth 2,213 million euros of public resources, has secured, for the first time, the computerised management of 8,422 FDPs, with a significant improvement in the coordination between central and branch offices responsible for assessing the admissibility, eligibility and technical-administrative investigation of the applications relating to sub-measures 4.1 and 6.1 and to operation 6.4.a.

At the time of the publication of call for sub-measure 4.1 in 2017, the offices managed 2,522 applications with an allocation of public resources equal to 100 million euros to which have been added 1,964 applications for the sub-measure 4.1 call in 2020 whose budget is 40 million euros.

Sub-measure 6.1, activated in 2017 with the "young farmers package" call and with a budget of 235 million euros, collected 3,189 applications. The package provides, along with the support for the establishment of the young farmer as a farm manager, the obligation to activate at least one of sub-measures 4.1, 8.1 or operation 6.4.a. This led to different configurations based on the composition of the investment package (Fig. 4).

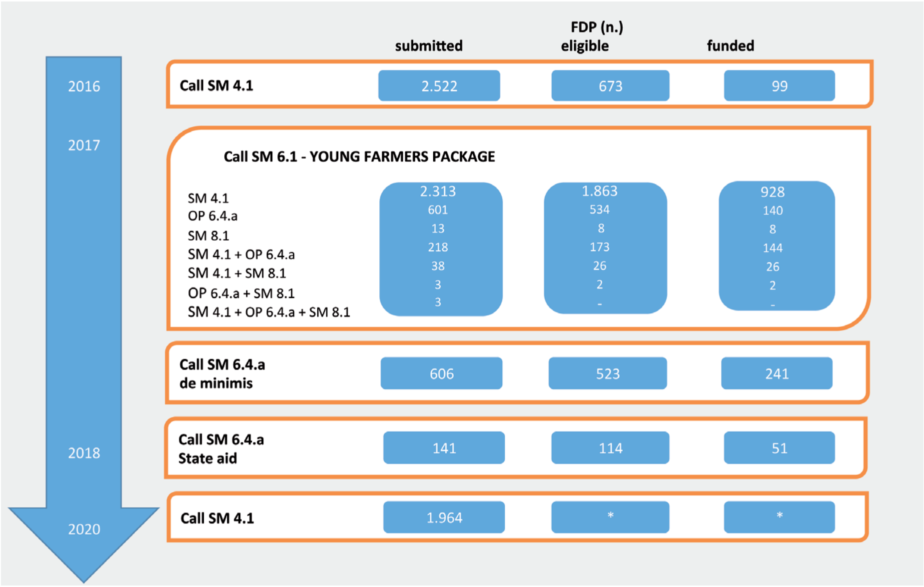
In order to support farm diversification, through the creation and development of non-agricultural activities, according to the provisions of operation 6.4.a, 606 applications were submitted under the call (de minimis scheme with a budget of 25 million euros) and 141 applications under the "Agritourism" call published in 2018 (state-aid scheme with a budget of 20 million euros).

Figure 4 - Main information stored in the PSAWeb Sicilia Database by category



Source: CREA-PB.

Figure 5 - FDPs submitted, eligible and recipient by sub-measure/operation



Source: our elaboration on PSAWeb Sicilia data (last update on 31/01/2021).

In terms of analysis, FDP data and information stored in the database ensure the same level of detail for the applications submitted as well as for the eligible to the technical-administrative investigation and for the recipient ones.

The varied information of the submitted FDPs gave a significant representation of the actual need of the regional agricultural system in terms of modernisation and restructuring (Agosta *et al.*, 2020a), of establishment of young farmers (Agosta *et al.*, 2020b), of farm diversification (Agosta *et al.*, 2020c; Agosta *et al.*, 2020d).

The next phase of analysis, carried out on the group of FDPs eligible for the technical-administrative investigation, highlighted the effectiveness of the selection criteria in addressing resources towards types of farms and investment plans responding to the strategic priorities for Sicilian agriculture.

In anticipation of the publication of new calls, the Administration was also able to carefully evaluate the opportunity to review certain selection criteria and access requirements, also developing simulations based, for example, on the hypothesis of a maximum expenditure ceiling of the investment or a reserve of resources in favour of production sectors (animal husbandry) or territories (small islands) less involved in the previous call.

The third level of analysis concerned the projects funded according to the budget of the calls and it was focused on the expected effects of the investment plans, in terms of transversal and specific objectives of the sub-measure/operation.

Along with the analyses of the individual sub-measures/operations, the study of the FDP data provided the Administration with important elements on specific aspects (Agosta *et al*., 2020e) capable of better corroborating the contribution of the reports on previous assessment activities and sectoral analysis (Cagliero, Cristiano, 2013). Thus, the MA has guaranteed the production and collection of data which, along with the monitoring data, could be used by the independent evaluator of the Programme.

Among the main achievements, it should be noted the contribution to the communication activities related to the implementation of the Programme and the strengthening of the culture of local partnership to plan, implement and evaluate the interventions.

Finally, the objective of spreading the accounting knowledge, a priority action of CREA-PB within the FADN activity, has also materialised with the training of students of the Department of Agriculture, Food and Environment of the University of Catania in the use of the PSAWeb in order to offer an education more in line both with the innovation needs of farms and with the development of professional profiles that can really improve the implementation of policies.

The role of CREA-PB, in the context of the collaboration with the MA, fully responds to the institution's objectives in in relation to:

- the development of methodological instruments and tools for the management of the available databases in order to strengthen the analysis of the impact of European, national and regional agricultural policies on the agri-food system and on the country's public budget;
- support and advice to regional administrations and to representatives of companies for the definition of policy tools;
- economic and social assessment of investment needs and their impact on the regional agricultural entrepreneurship.

In this perspective, the set of information stored by PSAWeb Sicilia integrates perfectly with the databases managed by CREA-PB, as the common variables adopt the same definitions and classifications, and represents an important and very rich source of data and information for specific analysis. An example of this kind is the in-depth analysis on the relationships between the land market and rents and sub-measures 6.1 and 4.1 of the RDP Sicily 2014-2020, carried out as part of the institutional survey "Land and Rental Market" carried out annually by CREA-PB since 1947.

Table 2 - Main products produced as part of the PSAWeb data management activity

Software, database, processed data	PSAWeb Sicilia (http://psa.psrsicilia.it) Database Statistical Processing Cartographic processing
Technical support material	PSAWeb Compilation guides related to sub-measures/operations Methodological notes: • "Metodologia registrazioni BilancioSemplificato e PSAWeb - Insediamento a cancello aperto"; • "Calcolo della Dimensione Economica con le Produzioni Standard"; Glossary of terms used in PSAWeb; Correaltion table between type of costs and macro-objectives per sub-measures/operations; Statistical simulation to support the preparation of calls; Statistical Processing and analysis.
Reports	1. Il fabbisogno di investimenti delle aziende agricole: una lettura della sottomisura 4.1 PSR Sicilia 2014-2020 attraverso i Piani di sviluppo aziendale, CREA, Roma, 2020 (www.reterurale.it/flex/cm/pages/ServeBLOB.php/L/IT/IDPagina/20909). 2. Insediamento giovani nel PSR Sicilia 2014-2020: la lettura del fabbisogno attraverso il Piano di sviluppo aziendale della sottomisura 6.1, CREA Roma, 2020 (www.reterurale.it/flex/cm/pages/ServeBLOB.php/L/IT/IDPagina/21422). 3. Il supporto alla diversificazione dell'attività agricola verso la creazione e lo sviluppo di attività extra-agricole: una lettura della operazione 6.4.a Agriturismo Aiuto in esenzione del PSR Sicilia 2014-2020 attraverso i Piani di sviluppo aziendale, CREA, Roma, 2020 (www.reterurale.it/flex/cm/pages/ServeBLOB.php/L/IT/IDPagina/21962). 4. Il supporto alla diversificazione dell'attività agricola verso la creazione e lo sviluppo di attività extra-agricole: una lettura dell'operazione 6.4.a in regime de minimis del PSR Sicilia 2014-2020 attraverso i Piani di Sviluppo Aziendale, CREA, Roma, 2020 (www.reterurale.it/flex/cm/pages/ServeBLOB.php/L/IT/IDPagina/21959). 5. Il fabbisogno di investimenti delle aziende agricole siciliane attraverso la lettura dei Piani di Sviluppo Aziendale del PSR Sicilia 2014-2020, CREA, Roma, 2020 (www.reterurale.it/flex/cm/pages/ServeBLOB.php/L/IT/IDPagina/22079).
Thematic focuses	Relazioni tra mercato fondiario e degli affitti e sottomisure 6.1 e 4.1 del PSR Sicilia 2014-2020, in Andrea Povellato, Davide Longhitano (a cura di): Indagine sul mercato fondiario in Italia – Rapporto Regionale, CREA, Roma, 2020 (www.crea.gov.it/documents/68457/0/CREA_PB_Rapporto_Regionale_MF_2019.pdf/c40dfe48-f87d-db70-fcba-95cc4914aa6b?t=1615395625164). Thematic studies: Labour, farm profitability, irrigation systems, mechanisation, land needs.

Source: CREA-PB.

4. Conclusions

The close collaboration between the MA and CREA-PB, aimed at designing, developing and adopting PSAWeb Sicilia, allowed to meet various institutional, knowledge and research needs. In particular, the Regional Administration has acquired a series of elements useful to verify the compliance with regulatory obligations, to assess the effectiveness and efficiency of the resources allocated for the implementation of generational renewal and to enhance the competitiveness and profitability of farms. CREA-PB obtained a set of data and information for carrying out analyses and studies in the research areas corresponding to the mission of CREA-PB.

Furthermore, the statistical basis generated by PSAWeb represents a rich source of information on rural development to be exploited both to improve the evaluation of the effectiveness and impact of some investment measures of the current programming period and to support the work of the regional technical groups engaged in the construction of the path for defining the post-2020 CAP strategy.

It should be emphasised that, although the observations collected by PSAWeb cannot be regarded as a representative sample, since they have not been selected according to appropriate statistical methods, their number – more than 8,400 in January 2021, to which we have to add the FDPs related to new calls that will be published until the end of RDP implementation – allows to outline an important cross-section of the Sicilian agricultural system, with a unique, broad and detailed perspective, thanks also to the specificity of the collected information.

By virtue of the modular and flexible structure one of the most interesting aspects of the application is the possibility of further developments in terms of functionality and replicability in other realities. For instance, the Regional Administration has expressed the need to monitor, with precision and immediacy, the progress of the implementation of the individual projects. This would allow, on the one hand, the analysis of the real effects of the investment at farm level and, on the other hand, the verification of the achievements of the sub-measures/operations objectives identified by the RDP.

Another option for strengthening the application could be the integration with data from other sources, such as AGEA. The eventual link with the farm file is already set up thanks to the alignment of the AGEA land use codes with the FADN Farm Return headings.

Particular attention should be paid to improve the application in order to monitor the implementation of interventions, even in progress. This aspect is of central importance in the results-based approach (New delivery model) introduced in the proposal for a regulation of the New CAP (COM (2018) 392 final) which links the payment of subsidies to the achievement of the objectives included in the Strategic Plan (COM (2018) 392, art. 65, no. 7).

Table 3 - Context indicators available on PSAWeb Sicilia

Dimension	**Codes**		**Indicator**	**PSAWeb data**
	PMEF 2021-2027	**QCMV 2014 -2020**		
Farms and farmers	C.12	C.17	Agricultural holdings (farms)	Number of agricultural holdings Agricultural size of the holdings - in utilised agricultural area (UAA) size classes Economic size of the holdings - in standard output (SO) classes Labour force - in persons and in annual work units (AWU) Average size of the holdings - physical (UAA), economic (standard output), labour in persons and AWU
	C.13	C.22	Farm labour force	Family labour force (sole holders working in the farm + members of the sole holder's family working in the farm) Non-family labour force
	C.14	C.23	Age structure of farm managers	Farm managers by age groups
	C.15	C.24	Agricultural training of farm managers	Basic education (qualification) Agricultural education (qualification)
	C.16 - **NEW**		New farmers	Number of young farmers
Agricultural land	C.17	C.18	Agricultural area	UAA per Type of farming
	C.18 - **NEW**	C.20	Irrigable area	Irrigable and irrigated area
	C.19	C.34	Farming in Natura 2000 areas	UAA
	C.20	C.32	Areas facing natural and other specific constraints (ANCs)	UAA per Type of area
	C.21 - **NEW**		Agricultural land covered with landscape features	UAA

Table 3 - Continued

Dimension	**Codes**		**Indicator**	**PSAWeb data**
	PMEF 2021-2027	**QCMV 2014 -2020**		
Livestock	C.22	C.21	Livestock number	LU (n.)
	C.23 - **NEW**		Livestock density	LU/UAA
Agricultural and farm income	C.24	C.25	Agricultural factor income	Agricultural factor income
	C.25	C.26	Agricultural entrepreneurial income	Agricultural entrepreneurial income
	C.26	-	Farm net value added	Farm net value added
	C.27	C.28	Gross fixed capital formation in agriculture	Fixed capital
Agricultural productivity	C.29	C.14 C.15 C.16	Labour productivity	Labour productivity

Source: our elaboration on QCMV 2014-2020, PMEF 2021-2027 and PSAWeb Sicilia (last update on 31/01/2021).

The logical evolution of PSAWeb Sicilia is the replicability of its use at national level, or where the activities of monitoring, evaluating and analysing the measures under the RDP and the NSP, are inefficient, inadequate or difficult.

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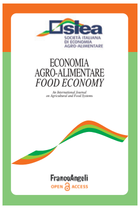
Economia agro-alimentare /
Food Economy

An International Journal on Agricultural and Food Systems

Vol. 23, Iss. 3, Art. 3, pp. 1-24 - ISSN 1126-1668 - ISSNe 1972-4802
DOI: 10.3280/ecag3-oa12769



Ten years after: Diffusion, criticism and potential improvements in the use of FADN for Rural Development assessment in Italy

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Abstract

This article aims to contribute to the debate about the Farm Accountancy Data Network (FADN), on how to make it more usable, useful and reliable, both for research users and practitioners when studying policy assessment. Ten years ago, the Italian National Rural Network published a highly relevant report about FADN data use for Rural Development policy evaluation, providing a wide range of examples of its application. The report had the merit of providing a comprehensive and systematic overview of FADN uses for evaluation for the first time and not only for impact assessment. From this experience, this paper examines how the different Managing Authorities in Italy have used FADN data for the evaluation of the current 2014-20 Rural Development Programmes: how actually the database has been used in the Annual Implementation Reports, with a focus on indicators for competitiveness assessment. The paper highlights some recommendations, considering the next programming period and the application of the so-called New Delivery Model.

Article info

Type:
Article
Submitted:
07/05/2021
Accepted:
20/09/2021
Available online:
12/01/2022

JEL codes:
Q18, Q12, D04

Keywords:
FADN
Evaluation
CMEF
Rural Development

Managing Editor:
Lucia Briamonte,
Luca Cesaro,
Alfonso Scardera

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Introduction

The evaluation always involves a judgment of the interventions according to their effects on the needs they aim to satisfy. It is a systematic tool which provides evidence for decision-making and improves effectiveness, usefulness, and efficiency. Moreover, the evaluation contributes to improve transparency, learning and accountability (Cagliero & Cristiano, 2013).

As known, there is a wide range of methodologies that can be applied, depending on several issues (as type and approach of evaluation, data availability, specific topics, …); so, it is possible to state that there is not a single method that can provide a right evidence, but only a deliberate choice of suitable combination of methods could lead to sounding answers to evaluation questions (European Commission, 2014). However, the main challenge is always to find good counterfactual/control/benchmark. The next big question is: which are the data sources that can positively and reliably be used in evaluation exercises?

In terms of quality and *a priori* expectations, any data source is better than another: assessment objectives and information availability should guide analysis and choices. Different sources mean different information: i) monitoring data and administrative ones are exclusively focused on beneficiaries; ii) official statistics concern a region, a population, or a sector; iii) direct surveys, both on beneficiaries and non-beneficiaries' side, are high costly in time, money and human resources.

The Farm Accountancy Data Network (FADN) can be used for different tasks of Common Agriculture Policy (CAP) analysis (context description; justification of support) and assessment (ex-ante, thematic, ongoing, ex-post evaluations) and provides a wide range of useable indicators and indices, the structural ones (e.g., the intensity of inputs) and the economic ones (e.g., labour productivity, the impact of support, etc.). However, FADN data requires some care and caution (European Commission, 2021a and 2021b).

In 2011 the Italian National Rural Network (NRN) published a report on FADN use for Rural Development policies' evaluation (Cagliero *et al*., 2011), providing a broad overview of its potential uses and describing several and concrete examples of its application. The report aimed to give account of a wide range of different FADN uses, not only for impact assessment or context analysis, but providing, for the first time, a full and comprehensive overview of its uses. That document has the merit of having triggered an important debate on the concrete possibilities of using FADN in evaluation exercises in the community of researchers and evaluators, but also involving the various Managing Authorities and the Commission services.

Ten years after that experience, this article aims to analyse the use of FADN, in light of evaluation activities of the 2014-20 Rural Development Programs (RDP). The analysis is based on the 2019 Annual Implementation

Reports (AIR) and it focuses on evaluation results related to the Common Evaluation 27 (CEQ): "To what extent has the RDP contributed to the CAP's goal of fostering agricultural competitiveness?". The objective is to highlight any methodological developments adopted by the Independent Evaluators to answer this impact evaluation question, using the FADN data individually or matching them with other data sources.

The manuscript firstly presents the main elements of 2014-20 Rural Development (RD) assessment as far as questions, indicators, data and sources; Then it focuses on FADN data uses in the Italian RDP evaluations, synthesized in the 2019 AIRs, highlighting the different approaches. After a discussion on the main results observed, in the view of critical issues and possible solutions, some conclusions with a perspective on the next programming period end the paper.

1. The CAP 2014-20 evaluation at a glance: questions and indicators

During the different programing periods of Rural Development, the Commission has boosted the importance of the so-called strategic approach, that provides a closer and more addressed relationship among the need's assessment, the identification of objectives and the choice of measures. Following this approach, the Commission introduced, and enhanced, a common vision of a monitoring and evaluation framework, providing a common ground Europe-wide. In this context, emphasis was given to the use of indicators and a particular attention was paid to the data sources to support and evaluate policies in the agricultural sector (Scardera, 2008; Mantino, 2008).

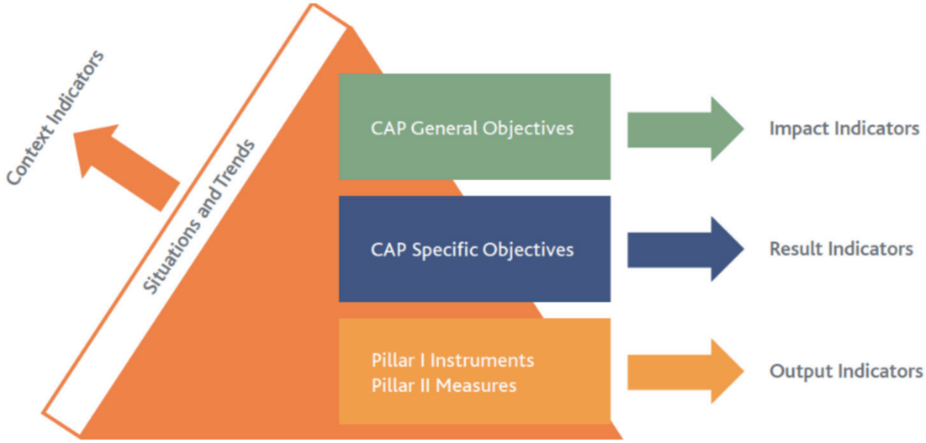
The Regulations during the 2014-20 period confirm the importance of evaluation: it provides evidence, transparency, learning and accountability for decision-making and improves the effectiveness, utility, and efficiency of RD interventions.

The European Commission (EC) has strengthened the vision of a "one-fit-all" system within the Common Monitoring and Evaluation System (CMES)[1] presented in the Technical Handbook (European Commission, 2017). The CMES includes the so-called indicator plan (common context/impact, output, result, target indicators), the Common Evaluation Questions, the Evaluation Plan and a list of guidance documents. In accordance with the past, the

1. In the programming period 2014-2020 there is often confusion between what is the Common Monitoring and Evaluation Framework (CMEF) and the Common Monitoring and Evaluation System (CMES). The CMEF 2014-20 is the compilation of rules and procedures necessary for evaluating the whole CAP; whilst the CMES contents the rules and procedures within the CMEF, which relate only to rural development policy or Pillar II of the CAP (European Commission, 2017).

general objectives shall be assessed using common impact indicators, while the specific objectives shall be assessed by using common result indicators. The information shall be gathered from established sources of data, such as Eurostat and the Farm Accountancy Data Network.

Figure 1 - Relations among indicators in 2014-2020 CMES



Source: European Evaluation Helpdesk (2019).

European Commission provided detailed fiches for each of the common indicators and among those 13 impact indicators shall be used to assess RDPs impacts. For example, three of these are directly related to the CAP Objective – "Fostering the competitiveness of agriculture". They are I.01 Agricultural entrepreneurial income; I.02 Agricultural factor income; I.03 Total factor productivity in agriculture. As context indicators, these indicators are already available and calculated at macro-level for each Member States (Economic Accounts for Agriculture), but they cannot be directly related with RDPs interventions. Indeed, changes in these indicators at aggregate level (sector) could only represent a gross effect caused by several factors and prove to be of little use in analyzing the actual RDPs effects. For this reason, indicators I.01, I.02, and I.03 should be calculated primarily at micro-level both for a group of beneficiaries and a control group (non-beneficiaries). In this goal, the Technical Handbook indicates the FADN as a relevant source and suggest this database to be used for the quantification of those indicators, as impact indicators[2] (Table 1).

2. The availability of standardized datasets (e.g. input/output tables for EU Member States, FADN data) is a great advantage for quantitative methods. There are significant economies of scale for methods using such data (European Commission, 2014).

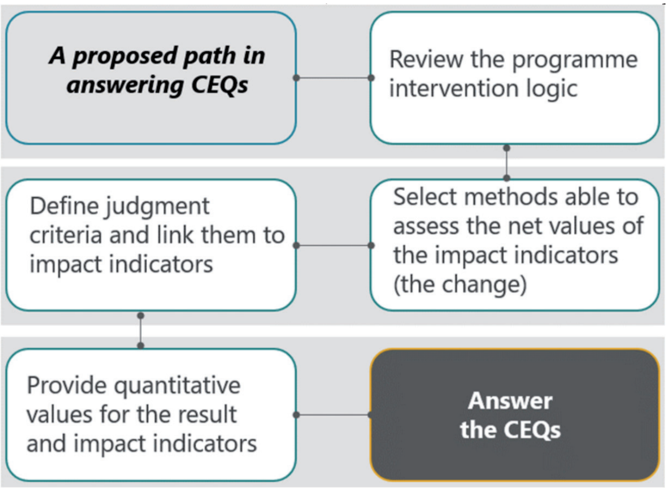
Table 1 - List of proposed sectorial impact indicators using the FADN for RDPs assessment

Sectorial Indicators	**Proposed utilisatioin**	**Calculation form FADN Codes**
I.01 - Agricultural entrepreneurial income (Per Annual work units (AWU) in agriculture)	Agricultural entrepreneurial income measures the income derived from agricultural activities that can be used for the remuneration of own production factors, i.e. non-salaried (= family) labour, land belonging to the agricultural holding and own capital. It is obtained by deducting wages, rent and interest payments from agricultural factor income	(SE135 + SE206 – SE275 –SE360 + SE600 – SE365)/SE010 *SE135 = Total Output crops and crop production* *SE206 = Total Output livestock and livestock products* *SE275 = Total intermediate consumption* *SE360 = Depreciation* *SE600 = Balance current subsidies and taxes* *SE365 = Total external factors (wages, rents and interest paid)* *SE010 = Total labour input in full time equivalents*
I.02 - Agricultural factor income (per annual work unit (AWU))	Agricultural factor income measures the remuneration of all factors of production (land, capital, labour) regardless of whether they are owned or borrowed/rented and represents all the value generated by a unit engaged in an agricultural production activity. It corresponds to the net value added at factor cost	(SE135 + SE206 – SE275 –SE360 + SE600)/SE010 *SE135 = Total Output crops and crop production* *SE206 = Total Output livestock and livestock products* *SE275 = Total intermediate consumption* *SE360 = Depreciation* *SE600 = Balance current subsidies and taxes* *SE010 = Total labour input in full time equivalents*
I.03 - Total factor productivity in agriculture	Total factor productivity (TFP) compares total outputs relative to the total inputs used in production of the output. TFP reflects output per unit of some combined set of inputs: an increase in TFP reflects a gain in output quantity which is not originating from an increase of input use	Output (n=3): Crop Production (FADN SE135), Livestock Production (FADN SE206) and Other Output (SE256) in nominal (basic) values Inputs/Factors (m=4): Labour in AWU (FADN SE010), UAA (FADN SE025) in hectares, Working Capital (FADN SE275 [intermediate consumption]) in nominal value, Fixed Capital (FADN SE360 [depreciation]) in nominal value

Source: European Commission (2018a).

In the enhanced Annual Implementation Report, Member States (MS) shall report findings on their evaluation by answering the Evaluation Questions. To provide support to MS and evaluators, the European Evaluation Helpdesk introduced two dedicated documents: "Guidelines. Assessment of RDP results: How to prepare for reporting on evaluation in 2017" and 'Approaches to assess RDP achievements and impacts in 2019", recommending several approaches for answering CEQs[3]. The document related to 2019 AIR, particularly, provides a range of possible techniques to be applied in optimal data-situations as well as in data gap ones; qualitative methods are also included. The document is organized in different sections by each evaluation question, but it proposes however a general path to identify the most suitable method based on data availability (Figure 2) (European Commission, 2018b).

Figure 2 - Common Evaluation Questions: general recommended steps



Source: European Commission (2018b).

The Evaluation Helpdesk also provided an interactive decision tool, 'Data for the assessment of RDP achievements and impacts', which intends to orient the choice of evaluation approaches and data in quantification of impact indicators (European Evaluation Helpdesk, 2019). The tool transfers

3. It is to be underlined that all the Helpdesk guidelines and working documents are non-binding document, which aims to facilitate the exchange and learning from practices to improve the quality of evaluations of RDPs 2014-2020.

the logic frameworks developed in the Guidelines mentioned above into an interactive format, providing further detailed and practical information and recommendations on what to do in case of data gaps both in the short and long term, when solutions are needed. The interactive tool consists of a set of seven logic models covering the 13 common impact indicators and the micro approach using FADN for the quantification of indicators I.01, I.02 and I.03 is strongly confirmed.

2. Evaluating Rural Development Programs using FADN data

As mentioned, the range of methodologies that can be applied to evaluation is very wide and no single method can claim a monopoly for provision of right evidence, but a suitable choice of combination of techniques can lead to robust answers to evaluation questions. Variants of evaluation methods range from more "naïve" approaches, i.e. beneficiaries' opinion on programme effects or comparisons of the outcomes of participants with their pre-programme situations, to more rigorous experimental and quasi-experimental approaches. This process of choice is always very complex and requires robust skills and is based on several elements, among which attributes, availability and detail of potentially usable information are highly determining factors.

As the Farm Accountancy Data Network collects farms' structures, income and performance data, it always has been – and still is – considered a very useful source that meet the information demands in programming and assessing RDPs (European Commission, 2010; European Commission, 2021b; Abitabile & Scardera, 2008).

The FADN is the only harmonized data archive on farms that covers the entire European Union by region and contains, in Italy, about 2,000 elementary pieces of structural, accounting, and non-accounting information for each farm in the network, along different years. Over the years several changes have been introduced in the FADN which, at the beginning, was specifically built to collect farm accounting data and to analyze farm revenues. As a result, currently FADN allows the use of different assessment models and the possible application of many techniques, as exemplified in Table 2.

The Evaluation Handbook confirms the main points of strength in the use of FADN: i) it is the only common European source of microeconomic data; ii) the bookkeeping principles are the same in all countries; iii) farms are selected on the basis of sampling plans at the level of each region in the Union. However, the Handbook recalls some well-known critical issues: i) the survey does not cover all the agricultural holdings; ii) the methodology

Table 2 - Summary of proposed FADN uses in RD evaluation

	Context and needs assessment	**Implementation and performance assessement**	**Economic justification via comparation**	**Effect (Impact) assessment**
Type of indicators	Context Baseline	Result Specific	Specific	Baseline Result
Type of approach	Benchmarking Scenarios Parameterization	Pre - post Profiling Selection criteria	Partial budgets Farm balance sheets Tec. Coeficient	Shift-share Comparison group design Statistical matching
Example of indicator	Labour productivity	Gross Value Added	Costs and income	Farm Net Value Added
Examples of techiques	Analysis by groups Chain of indices Farm profitability	Scenario Sensitivity Profiling	Fair compensation CEA Loss of income	Regression PSM and DiD Naïve Comparison
Examples of references	Borsotto, 2019 Cagliero *et al.*, 2011	Cagliero *et al.*, 2021 NUVAL, 2016	Seroglia and Trione, 2002 INEA, 2014	Cisilino *et al.*, 2013 EC, 2018a Michalek, 2012
Notes/ caveat	Missing information	Rotation of farms	Representative-ness	Satellite samples

Source: authors' elaboration from Cagliero *et al.* (2011).

applied provides representative data only along three dimensions (territory, economic size, and type of farms). The evaluator must take into consideration also the delays in the provision of FADN data (2 years) and be aware on how the sample relates to the whole population; the evaluator needs to clearly recognize which *segment* of the supported farms list is included in FADN survey.

At the end of April 2021, the Evaluation Helpdesk made available a further report on best uses of FADN for the assessment of RDP in the view of agriculture competitiveness (European Commission, 2021b). This document proposes practical solutions and examples from various Member States experiences and describes what should be considered when using FADN data in assessing Rural Development effects on competitiveness and answering the related CEQs. These issues are discussed following some guiding requests as well as:

1. What are the basic sources of farm-level data, which can enable evaluators to answer CEQs?
2. Why is farm-level data essential to answering CEQs on competitiveness?
3. Are the variables available in the FADN sufficient to estimate the RDP's effects?
4. What requirements are needed from a sample of data at farm-level to be used for answering the CEQs?
5. Given that the FADN is the first choice as a data source for the calculation competitiveness parameters, how can the FADN be utilized to answer CEQ 27?

3. Using FADN answering the common question on agricultural competitiveness

In contrast with the previous period (2007-2013), for 2014-20 there is no Mid-Term Evaluation and evaluation outcomes are reported during the programme in the so called in chapter 7 of enhanced Annual Implementation Reports. The AIRs in 2017 include the quantification of RDP's achievements; judgment criteria are provided by Evaluation Helpdesk to interpret result indicators and to answer the Focus Area Common Evaluation Questions 1-21 (European Commission, 2016). The AIRs submitted in 2019 require an update of these evaluation findings and, in addition, they are expected to include (European Commission, 2018a): i) the assessment of the RDP's impacts (net values of impact indicators); ii) RDP's contributions towards the European Union strategies; iii) the answers to all the CEQs, including those related to the European level objectives EQ (22-30).

The analysis of the outcomes related to the Italian RDPs evaluations has been carried out from 2019 AIRs in relation to the quantification of impact indicators I.01, I.02 and I.03 in answering the Common Evaluation Question 27: 'Fostering the competitiveness of agriculture'. In the EC guidelines the use of existing data is highly recommended for this evaluation exercise. It is suggested to cross-reference FADN micro level data with the information related to beneficiaries stored in the Information Systems (administrative data) and then put the coming results in comparison with macro level tendencies, following a two stages approach.

Table 3 summarizes the results of the documentary survey by classifying the Italian Regions into four levels of quantification of the indicators analyzed in the 2019 AIRs (AIR, 2019).

Generally, a relevant effort to answering the Evaluation Question by the quantification of these common impact indicators using FADN data is found. But some evaluators argue that it is not possible to quantify any effect at the current stage of projects' uptake; they do not use FADN data to calculate indicators and they will not use them in the coming years (- indicators not quantified)[4].

In six Regions (^ - quantification is only planned), it is possible to observe a sort of willingness to use FADN data for the quantification of impact indicators, although this has not yet been done because the timing of data. According to the evaluators, these estimations should be made over a sufficient period in which the effects of the RDP can be assessed. This implies, as example, being able to detect the first effects on projects concluded in 2017 only through FADN data available in 2020, referring to 2017 to set the pre-intervention situation and referring at least to 2019 to estimate the post-intervention change.

Table 3 - Uses of FADN for estimating impact indicators and answering CEQ 27

RDP	I.01	I.02	I.03	Indicator specific/ proxy	Use/Notes	Evaluation Services
Valle d'Aosta	^	^	^	–	Qualitative approach	Lattanzio Advisory
Piemonte	*	*	*	–	Necessity data panel	Ires Piemonte
Lombardia	X	X	X	Output/cost; FNVA/ AWU; FNI/FWU	Counterfactual Approach; Economic context	Agriconsulting
PA Trento	X	*	*	–	–	IZI
PA Bolzano	X	*	*	FNI	–	RTI IZI-Apollis OHG
Veneto	X	X	X	Output/costs; FNI/ FWU	Counterfactual Approach; Economic context	Agriconsulting
Friuli V.G.	–	–	–	–	–	Ismeri Europa
Liguria	–	–	–	GVA/AWU	Benchmarking	Lattanzio Advisory

4. In the case of Liguria, however, the FADN is used to estimate result indicator R2, "Change in Agricultural output on supported farms/AWU (focus area 2A)".

Table 3 - Continued

RDP	I.01	I.02	I.03	Indicator specific/ proxy	Use/Notes	Evaluation Services
E. Romagna	X	X	X	Output/costs; FNI/ FWU	Counterfactual Approach; Economic context	Agriconsulting
Toscana	^	^	–	–	–	Lattanzio Advisory
Umbria	^	^	–	–	–	Lattanzio Advisory
Marche	^	^	–	–		Lattanzio Advisory
Lazio	*	*	–	FNI/FWU	EU FADN database	Cogea
Abruzzo	X	X	X	–	Statistical matching	ISRI
Molise	–	–	–	–	–	NVVIP
Campania	^	^	–	–	–	Lattanzio Advisory
Puglia	^	^	–	–	–	Lattanzio Advisory
Basilicata	–	–	–	–	–	NVVIP
Calabria	X	X	X	–	Econometric Model; Statistical matching	RTI ISRI-Sinapsys
Sicilia	*	*	–	–	PSAWEB	RTI ISRI-AGROTEC
Sardegna	X	X	X	–	Statistical matching	RTI ISRI-PWC-Interforum-Primaidea
PSRN	*	*	*	–	–	Lattanzio Advisory

X → full quantified; * → context update; ^ → planned to be done; – → not quantified.
FNVA: Farm Neta Value Added; FNI: Farm Net Income; AWU Agricultural Work Unit; FWU: Family Work Unit; GVA: Gross Value Added

Source: authors elaboration from 2019 AIR – Italian Regions

In four Regions (* - context update) the evaluators estimate only the gross change in the economic context, without assessing the direct contribution of the RDPs, but they argue any way that FADN is the main source to be used for this purpose. In Piemonte, the evaluators aim to use three-year average values to assess those issues, considering the rotational nature of the FADN panel and the variability of agricultural results caused by weather conditions occurred in the last years; this has prevented the possibilities of assessing the contribution of the RDP in the 2019 AIR. In the case of Lazio Region, the estimation has been carried out, unlike the other cases, using the European FADN and not the Italian database[5].

In the remaining eight Regions (X - full quantification), the use of FADN data for the quantification of impact indicators I.01, I.02 and I.03, in answering to Common Evaluation Question 27, has been different among the evaluators.

The evaluators of Sardegna, Calabria and Abruzzo's RDP use FADN for estimation of both beneficiary and non-beneficiary groups and the exercise is focused entirely on transitional operations related to the previous programming period. Evaluators highlight the FADN sample is unbalanced in terms of economic size compared with the beneficiary group; this problem has required a downsizing of the sample with a loss of significance and robustness. Furthermore, the rotational nature of the panel leads to a critical issue: the number of constant observations over a minimum time is very small and did not allow counterfactual analyses. However, the evaluators intend to use FADN for future analysis. Towards the ex-post evaluation, it's planned to gather a direct survey on subsidized farms to be compared with a sample of non-treated ones, using FADN and applying a statistical matching procedure.

The evaluator teams of Trento and Bolzano's Programmes point out some caveat; they argue that the contribution of the RDP to farm income is underestimated because the value is too variable according to the type of farming. To estimate the effects of the investment supported, analyses are carried out on monitoring data integrated by a direct survey conducted at project check, while FADN data are used to analyze the economic dynamics in different sectors. Furthermore, evaluators state that the RDP provides effects on labour productivity rather than on business profitability[6].

For the estimation of the impact indicators for Lombardia and Emilia-Romagna, the data estimated in 2007-13 Ex-Post Evaluation and the FADN data available until 2016 are used. In evaluators point of view, the difference between the situation with RDP (FADN data) and without RDP (estimated values) allows to appreciate the potential impact of the interventions. In the case of Veneto, the analysis is carried out using the results of a direct survey

5. There are some differences between the two sources, first of all the different informative detail which is considerably higher from the Italian one.

6. It could mean a criticism in terms of relevance of indicators.

on beneficiaries (factual group), while the FADN is used to build up the control group.

Finally, a relationship between FADN data use to answer the CEQ 27 and the evaluation team has to be highlighted. From the comparison between the analysis conducted on the 2019 AIRs and the evaluation service assignments (Table 3), some evaluators show a deeper interest in the use of FADN data. It is because of a more structured and continuous relationship with both the Managing Authority and the CREA-PB offices, which manage the FADN surveys. In particular, the CREA-PB, as well as the former INEA, has provided during the years several documents explaining the use of the database, such as "L'archivio RICA per valutazione" (INEA, 2003).

4. Discussion: uses, criticism and possible improvements in FADN uses

In this section, a discussion of the results obtained in the previous chapter is presented, following, where possible, the guiding questions proposed by the European Commission (European Commission, 2021b) on best uses of FADN for the assessment of RDP and reported at the end of Chapter 2.

In relation to the first question proposed regarding which data sources can be used for evaluation, most Italian evaluators point out the FADN could be considered the most appropriate and usable source; other information taken into consideration are those deriving from official statistics sources, for example by ISTAT, or administrative indications, while in rare cases recourse was made to direct surveys.

The analysis underlines how relevant could be conducting assessment under a counterfactual approach, comparing groups of beneficiaries and non-beneficiaries. In this light, detailed information available at the farm level in the most complete way sound necessary (guiding question 2 – Why is farm-level data essential to answering CEQs on competitiveness?).

Regarding the ability of the variables collected by the FADN to be sufficient to conduct evaluations as requested in question 3, two distinct reflections should be made. The analysis here presented concerns the theme of competitiveness (CEQ 27) only and in this case the FADN economic variables are judged adequate and also capable of determining some additional indicators (e.g., Output/cost) proposed by evaluators. On the other hand, the variables collected by the survey may not always be sufficient for assessments on other topics, such as climate change or quality of life in rural areas.

We may consider the next guiding question the most relevant, as it addresses the critical issues of appropriate samples to answer the evaluation questions. Considering Italian 2019 AIRs, it is possible to aggregate the main evidence about FADN data use and farm samples to answer CEQ 27, as well as some critical points and possible improvement; a synthesis matrix is hereby proposed (Table 4).

As pointed out, several evaluators used FADN data for the setting up of beneficiaries and control groups having similar characteristics in a counterfactual approach. This process has been set with different techniques, especially regarding the composition of the samples, whether in the treated group or in the untreated one. The evaluators highlight a critical issue related to the number of observations belonging to the database, especially when there is a need for in-depth analysis in terms of type of farming or economic size, e.g. small farms. In these cases, the solutions suggested are basically an extension of the FADN sample, through various methodologies, such as, for example, the use of databases from neighbouring regions or the activation of so-called satellite samples (Cagliero *et al*., 2011; European Commission, 2020).

An important aspect to be considered using FADN is the possibility given by time series analysis assured for more than 10 years, thanks to the continuity through time of the survey. However, even in this case several critical points must be highlighted, as the rotational nature of the panel provides a significant number of entries and exits of farms over time. Here again, the solution is most likely to set up a satellite sample, which would continuously survey farms that otherwise would be dropped out from the FADN sample (Abitabile & Scardera, 2008). This could ensure a constant sample of farms for an appropriate period of time, useful for the assessment (pre and post intervention). However, it should be noted that the satellite sample cannot improve the statistical representativeness of the basic sample, as it does not respect the same stratification criteria. It should therefore be considered as an "oriented (or guided) sample" addressed to collect information about RDP beneficiaries which can then be compared with the universe of farms represented by the FADN survey.

A simpler alternative to the satellite sample, even if less complete in terms of consistency, is to collect the technical-economic data on the beneficiaries through a specific application computing the farm's balance sheet. The application called "Bilancio semplificato" (simplified business budget), adopts a methodology comparable with the results of the FADN survey and provides several indicators to answer to the Evaluation Questions[7].

Finally, in relation to the last guiding question proposed by the Commission, regarding the best possible uses of FADN, it can be said that studies of a counterfactual nature, starting from the farm level, are indicated as the most appropriate to answer the common question in terms of

7. https://bilanciosemplificatorica.crea.gov.it.

Table 4 - Summary matrix on FADN uses, critical points and possible solutions

Actual use	Criticism	Possible improvement
Construction of groups of beneficiary farms and similar control groups	Low number of beneficiary farms	Sample extension methods Activation of satellite samples
Details by farm type and economic size	FADN sample not aligned to the population of beneficiaries	Activation of satellite samples
Use of deep time series (>10 years)	Rotational nature of the panel	Activation of satellite samples
Analysis of evolution in the regional context	Gross effects and not the atual RDP contribution	Benchmarking
Estimation of economic performance coefficients	Need for data from administrative source	Macthing with administrative archives

Source: authors elaboration from 2019 AIRs.

competitiveness. The attributes of the FADN survey and the possibility of constructing comparison groups between farms represents a sort of potential "golden standard", once the observed critical points on the samples have been resolved. In addition, the evidence estimated at farm level could also be traced to a macro level (European Commission, 2018a).

In other cases, to estimate the economic performance of subsidized farms, the evaluators have set the so-called technical coefficients from FADN data (Cagliero *et al.*, 2011); those estimated parameters are then applied on administrative data, containing generally structural but non economic information. Although this approach is somehow naïve, it represents a first effort towards the possibility to cross-refer administrative records to the FADN. This cross-reference is the most far-reaching and interesting proposal in the literature for improving the possibilities of using FADN in evaluation pathways (European Commission, 2014, 2020, 2018a, 2021a and 2021b).

Finally, another relatively widespread use of FADN has been the estimation of the economic evolution in the regional context, i.e. updating the context/impact indicators, to highlight changes at territorial or sectorial level. But we know that this estimation exercise is not able to capture the contribution of RDPs to these observed changes. The result is a gross and insufficient quantification of the intervention. However, this information can be used as a benchmark within a more refined analysis process.

We have to underline a limitation in the analysis of the current use of the FADN for evaluation in Italy, that is a criticality due firstly to the application of different methodologies in the assessment exercises. This variability, as summarized in Table 3 above, does not let possible comparability among the different evaluations carried out from Italian RDPs. Because of this limitation, it is complex to express a general judgement of these evaluations or propose a meta-evaluation exercise. This limitation can be found also in the European context, since cases of use of the FADN result in the Evaluation Helpdesk overviews as patchy and they do not allow any comparability (European Commission 2021a and 2021b). However, proposing an analysis at Member States level, however parcelled out and complex, and a comparison Europe wide could represent an interesting insight and the next step for this study.

5. Main conclusions and perspectives for the future

In order to assess RDPs' effects, a very specific knowledge is necessary.

The Programmes are very complex and the situations among the Italian Regions are heterogeneous. In addition, the estimation of an indicator, determining the net effects of an intervention, is particularly challenging in situations where data are scarce, RDP uptake is low, or where insufficient time and resources have been devoted to the evaluation exercise (European Commission, 2018b).

The availability of standardized datasets (e.g. ISTAT, FADN, IACS) represents a relevant advantage for the application of quantitative methods and FADN data are confirmed to be very useful. However, their usefulness is conditioned by some critical points (i.e. What if the sample size is too small?), that have to be overcome as presented above: using sample extension methods; activating satellite samples; matching with administrative archives. For RDPs evaluation purposes, these improvements should become a practice in all Regions, as a path to better identify causal effects, in the light of potential generalization and lacks the evidence gathered (European Commission, 2021a).

In the view of enlarging the FADN regional sample, considering other regions where a similar measure is applied could represent an interesting opportunity; therefore, the suggested solution to increase the sample size is to include "neighbouring" RDPs. In this process some caveat must been considered: i) using only very similar measures with similar eligibility criteria; ii) including the location of the farm as a control variable; iii) considering a shift of the programme's effect (European Commission, 2021a and 2021b).

Building up a satellite design, as integrative system of samples to the FADN, could improve robustness of analyses in evaluation. This would be helpful especially when there is a lack of information about some specific topics or interventions. Accordingly, satellite samples are made by those farms belonging to a specific measure's regional list of beneficiaries on which FADN methodology is then applied.

As known, it would be desirable to process data both from official and administrative sources, such as FADN or information from Payment Agency or Managing Authority. Considering different databases is always a challenge the evaluator has to be ready to deal with. This topic has led to a growing literature about appropriate methods (Sinabell & Streicher, 2004; Michalek, 2012; European Commission, 2010, 2021a and 2021b). In matching different sources, comparable data are required to perform evaluations and such an approach would improve the validity of the evaluation studies considerably. To get integration of data belonging to different sources, it would be desirable to get the same definition of variables and indicators: this represents one of the main challenges. As regard FADN and monitoring or other administrative sources, we often have to face with a problem of data recording (because some of them are not mandatory and fields are not filled in) or with different definition/range/classification for the same information (Cisilino *et al.*, 2013; European Commission, 2020). Accordingly, this narrows the number of variables that can be used for statistical analysis (Counterfactual analysis, Statistical Matching) and the poor matching in the definition of variables leads to a large use of proxy variables. In this view, greater attention to the integration and the harmonization of information from the early stages of programming has to be the goal. This could be achieved through collaboration of all the subjects involved (Managing Authorities - Administrative information systems, Evaluators, Research sector).

Finally, data quality issue shall be strongly stressed (European Commission, 2021a). As known, data should be available, relevant, and consistent, as well as complete and precise. There should be no problem with the quality of FADN data in terms of completeness and time consistency[8] since a sophisticated quality check is done regularly.

The proposal for the new CAP 2023-27 includes some improvements through a New Delivery Model and organizational approach in relation of a new specific objectives' framework, which may reinforce future evaluations and nudge investigations forward new themes e new approaches, in the light of an innovating governance with the National Strategic Plan. We can then

8. In order to reduce the effects deriving from the rotation of the farms in the sample, a recent statistical weighting methodology has been developed, for stabilizing the results over time.

expect new fields of evaluation and new challenges in the definition of data and their use (Cagliero *et al.*, 2021; Cagliero *et al.*, 2020).

A data repository such as FADN, based on microeconomic data, therefore has obvious and relevant potential for estimating incomes and any changes triggered in agricultural enterprises, but it is also possible to identify new fields of analysis such as innovation, training and, above all, environmental and social sustainability, or thematic issue, such as agriculture in specific territories. These fields can be the topics to be addressed for future applications of FADN in an evaluation perspective (Cagliero *et al.*, 2019; Poppe & Vrolijk, 2016 and 2018) and several evaluation exercises in this sense are already available in Italy (Arzeni *et al.*, 2021; Cristiano & Proietti, 2019; Cagliero *et al.*, 2018; Cisilino *et al.*, 2019). In the view of the future National Strategic Plan, there are significant opportunities to improve the use of data for these issues, compared to the partial underuse that has occurred in the past, and in this sense the FADN improvement indications by the Commission are moving. Furthermore, the FADN can provide basic knowledge on local production systems at the microeconomic level and the strengths and weaknesses of agricultural holdings. This allows not only to highlight or verify any intervention needs but also to provide a baseline as a reference for subsequent evaluations.

Turning back to the Italian experiences, the lack of a systematic link between the databases relating to the agricultural sector and those relating, for example, to environmental parameters on a territorial scale, and the partial absence of functional georeferencing, represent critical points also for the future (Cagliero *et al.*, 2019). Probably these limits can be overcome with the transformation of the FADN towards the FSDN (Farm Sustainability Data Network) with the integration of environmental data also through the collection of data on the physical context in which the farm operates (Vrolijk & Poppe, 2021). Anyhow, it can be said that access to data, here understood as dialogue between different databases (e.g. with Agea data or data from six regional Information Systems), is confirmed as a critical point to be addressed and therefore this is the most important challenge in the coming years.

In this light, the governance system that will be adopted for the future National Strategic Plan will also have consequences on evaluation activities. Today, it seems difficult to imagine, especially for interventions deriving from rural development, a single evaluation of the future Strategic Plan, while a framework composed of punctual thematic and territorial evaluations and an overall meta-evaluation at the level of the National Plan is perhaps more likely. The example of the significant variability observed in the exercise here proposed on the competitiveness evaluation in the light of FADN uses brings out a possible critical point that leads to a reflection on applying common metrics in future evaluations.

Indicators are concepts, not only figures and their mere quantification cannot be the final goal of an evaluation process. It is very challenging to quantify impact indicators that are very narrowly defined, and these indicators are often not enough. From this background, the objective should be to achieve a broader view to monitor and analyse changes in the behaviours of farmers in a more consistent and trustworthy manner, using different and integrated sources of information, among which FADN plays an evident and relevant role.

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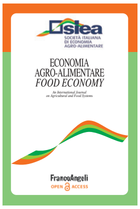
Economia agro-alimentare /
Food Economy

An International Journal on Agricultural and Food Systems

Vol. 23, Iss. 3, Art. 4, pp. 1-21 - ISSN 1126-1668 - ISSNe 1972-4802
DOI: 10.3280/ecag3-oa12771



Enhancing the Italian FADN for sustainability assessment: the state of art and perspectives

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Abstract

Farm Accountancy Data Network (FADN) is one of the most important microeconomic surveys in Europe. It collects information suitable for use in performing structural and socio-economic analysis of the agricultural sector in all the Member States. Contents and purposes have evolved over the time depending on the informative needs of the EU Commission and CAP's priorities. As a part of the Green Deal, CAP is expected to contribute to the environment, climate change and biodiversity objectives beyond 2020. In this new framework, one initiative launched inside the Farm to Fork Strategy has been the change of name from FADN to Farm Sustainability Data Network (FSDN) including variables related to the environmental and social aspects of farming. Like in other EU countries, the information collected by the Italian FADN exceeds that required by the EU regulations, allowing to some extent consideration of special characteristics of national agriculture. However, further variables could be added or changed, gathering them directly from the farmer, by including the existing database or through targeted questionnaires on FADN sub-samples. The new survey will maintain and improve the current role of FADN, reinforcing the analytical and political relevance of the network by adding further dimensions of sustainability. The discussion is on-going at EU and National level and this paper is a contribution to this debate. It gives a

Article info

Type:
Article
Submitted:
27/04/2021
Accepted:
18/09/2020
Available online:
12/01/2022

JEL codes:
Q12, Q56, R20

Keywords:
Farm Sustainability Data Network
Sustainability
Accounting system
Italian FADN

Managing Editor:
Lucia Briamonte,
Luca Cesaro,
Alfonso Scardera

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description of the environmental and social data gathered by the Italian FADN together with a consideration regarding about the opportunity and the possibility to enhance the system in view of the future period under evaluation. The switch to FSDN will require an effort from the Member States in terms of IT infrastructure, economic resources, new ways of collecting data and staff involved in data collection and the verification process.

Introduction

The Farm Accountancy Data Network (FADN) is one of the most important microeconomic accounting surveys collecting information suitable to be used to perform structural and socio-economic analysis of the agricultural holdings. It is a yearly survey carried out in all the Member States since 1965 and according to the same bookkeeping principles that make possible comparisons among different regions or countries. The FADN Farm Return collects more than 1,000 variables (Council Regulation EC 1217/2009).

When Common Agricultural Policy (CAP) was established, policies focused mainly on the optimum utilizations of the production factors. The primary aim of the network was to gather accountancy data for the determination of farm incomes and the assessment of CAP's impact on farm profitability. However, since 1980s, CAP measures have increasingly supported production methods oriented to the environmental protection and countryside maintaining; in 1992 the Council Regulation 2078/92 introduced schemes and methods compatible with the environment and further support was provided by Agenda 2000 programme which extend the adoption of agri-environmental measures under the Rural Development Regulation 1257/1999. In the last 20–25 years, agricultural policies have changed again, to meet new societal needs and priorities. CAP reform 2014-2020 has addressed commitments to economic, social, and environmental sustainability with the Rural Development Policy (RDP) oriented to improve competitiveness on agriculture, sustainable management of natural resources, climate change mitigation, balanced development among territories. As a part of the European Green Deal, CAP is expected to contribute to these objectives even beyond 2020.

New policy priorities lead to new data needs. According to the future strategy for agricultural statistics, there are three dimensions to cover: (i) economic dimension of agriculture regarding the production, market, and income of farmers; (ii) environmental dimension deriving by the sector's role as a user of natural resources and provider of environmental services; (iii) social dimension concerning living conditions, quality of life of farmers and rural households (European Commission, 2015). Although FADN is not officially a European statistic, is very close to the European Agricultural Statistics System (EASS) and is considered one of the most important sources of data for the analysis of agricultural policies. Even if not designed to satisfy environmental and social informative needs, characteristics as the annual data collection, the breakdown at farm level, the time-series, make FADN one potential tool for the assessment of farm-level sustainability (Kelly *et al.*, 2018). Among the more than 50 datasets included in the EASS, IACS (Integrated Administration and Control System) database managing CAP payment to the farmers and LPIS (Land Parcel Identification System) have the same detail level and frequency as FADN. But while IACS and LPIS offer little potential in terms of measuring farm-level sustainability because of the lack of social and environmental data, FADN is a more promising source for measuring sustainability.

Topics like environment, animal welfare, innovation, social aspects are limitedly covered by FADN. To fill this gap, a debate around the opportunity to improve the current scheme of the survey is being developed around the scientific communities, the DG Agri services and the stakeholders involved in the network. Projects like FLINT (Farm Level Indicators for New Topics in policy evaluation) have demonstrated how policy evaluation could be improved with a better and more complete data, covering new policy topics and multiple aspects of sustainability. This is the background against which the initiative to convert FADN in a Farm Sustainability Data Network (FSDN) has been launched inside the Farm to Fork Strategy with the aim to expand the scope of the current network, in line with the objectives of CAP and the Green Deal.

After the launch of the initiative[1], targeted consultations have been planned in May 2021 while a workshop is organized for June 2021. The adoption of the basic act proposal is scheduled for the second quarter 2022. At National level, the opportunity to modify the current set of information is currently under discussion in a working group, established inside the Policy and Bioeconomic Unit of the Council for Agricultural Research and Economics (CREA-PB). Italian FADN collects more information than those required by the EU regulation. Adding further environmental and social variables will permit to enhance the whole system and supply crucial information for the future evaluation analysis. The paper resumes the most important concerns of this debate, describing the key elements of a more sustainable Italian FADN system and how it will be possible to improve the survey including all the dimensions of sustainability. New information could be gathered adding the

1. https://ec.europa.eu/info/law/better-regulation/have-your-say/initiatives/12951-Conversion-to-a-Farm-Sustainability-Data-Network-FSDN-.

new variables in the current system's architecture while, in case of detailed or specific investigations, additional modules can be designed for sub-samples or for satellite samples. The paper is structured in a first paragraph that gives a background of the debate and how it has evolved in the European context. A short literature review regarding the use of FADN for environmental and social sustainability assessment is the focus of the second paragraph. The analysis of the Italian FADN is done in the third paragraph: normally used for the evaluation of farm costs, revenues and incomes, the survey is also a source of data of other kind of information regarding the sustainability of farm activities. These data, not collected in the EU FADN, are a strength of the national FADN but, nevertheless, there is room for improvement. Finally, the conclusions.

1. Background

One of the higher informative demands to FADN system in these last years is consequent to the new definition of the Common Agricultural Policy (CAP) that, according to the legislator, is going to be more coherent with the environmental legislation, more oriented to the knowledge, innovation, digitalization and more addressed to the achievement of the results. CAP is a part of the European Green Deal (Com (2019) 640 final 11/12/2019), the future European policies strategy which aims are, among others, the improvement of the food system (from the farm to the final consumer) and its connection with health and environment. These contribution are resumed in a recent document (Staff Working Document (2020) 93 fin) highlighting the role played by farmers, foresters, agri-food business and rural communities in (i) building a sustainable food system through the Farm to Fork strategy (Com (2020) 381 final 20/05/2020); (ii) protecting and enhancing the variety of plants and animals in the rural ecosystem as required by the new biodiversity strategy (Com (2020) 380 final 20/05/2020); (iii) contributing to the climate action of the Green Deal to achieve the goal of net-zero emissions in the EU by 2050; (iv) supporting the updated forestry strategy announced in 2021; (v) contributing to a zero-pollution action plan to be set out in 2021 by safeguarding natural resources such as water air and soil.

To be aligned with the Green Deal, the new CAP has included several measures: the eco-schemes, the strengthening of cross-compliance and several actions having as main aim the environment protection, the climate change mitigation, the improvement of agricultural statistics. More specifically, Member States are required to guarantee a better data quality, a set of indicators immediately updated for all the monitoring and evaluation activities, an increasing attention to the development of common and integrated approach in the collection and sharing of data. One of the instruments proposed by the Commission to reply to these requirements is the initiative to convert the Farm Accountancy Data Network (FADN) in Farm Sustainability Data Network (FSDN), according to a scheme more oriented to investigate the three dimensions of sustainability, beyond the economic one. This means a new approach to the survey, an integration of new variables, an estimation of new indicators more suitable to be used to measure the new phenomenon of the CAP. At EU level, the concept of sustainable development is becoming increasingly important and a key element of all the political strategies, including the agricultural ones. The EC has included three priorities in its Europe 2020 strategy and one of them is "Sustainable growth: promoting a more resource efficient, greener and more competitive economy" and also recognizes that agriculture delivers "multiple economic, social, environmental and territorial benefits".

The importance to have more complete and better data to improve policy evaluation has been explained and demonstrated in the FLINT (Farm Level Indicators for New Topics) project. Countries that have already gathered some of the sustainability data for a longer time in their National FADN seem to be able to perform better evaluation analysis of sustainability. In compliance with this evidence and with the new policy framework, the transformation process of FADN in FSDN has been launched at EU level: the number of new variables and the methods to collect the supplementary information are currently under discussion among the stakeholders involved in the survey.

Regarding the evaluation of rural development policies, an interesting workshop focused on data management for the assessment of RDP effects has been organized by the European Evaluation Helpdesk for Rural Development (EEHRD) (European Commission, 2020). The workshop (that took place online on 13-14 May 2020) offered insight into the use of existing data sources, the limitations and challenges encountered, and the solutions applied for better identification and use of data for evaluation purposes. The workshop culminated in several key lessons for the assessment of social, economic, and environmental effects and in a recommendation regarding the need for harmonization and integration of data sources. To perform the evaluation of socio-economic effects of the RD policies, the current lack of information could be covered using experimental approaches or additional surveys on the beneficiaries that can be combined with the existing datasets. This mean that FADN could be integrated with supplementary surveys or with additional samples if necessary. The same could be said for the evaluation of environmental effects where further efforts must be done to integrate and harmonize the existing sources of information not always aligned in terms of contents, quality of data, coverage, definitions and frequency.

This last aspect has a paramount importance considering that the future challenge of the EU agricultural statistics will be a planification of the survey systems to connect and integrate the existing databases.

The first important workshop specifically devoted to discuss the opportunity to convert FADN in FSDN was organized 8-9 February 2021 with the aim (i) to collect information on existing sustainability variables at EU and national level; (ii) to share information on tools that could be used to collect farm level data; (iii) to share private and public practices on data use for advising farmers. This workshop has given the opportunity to define a roadmap describing the problem to be tacked and the objectives to be meet, explaining why EU action is needed and outlining the policy options. In May 2021, a public consultation on this roadmap will be launched based on a target consultation questionnaire (topics on reinforcement and simplification of FADN): the target audience includes farmers, administrations, data collectors, advisors, researchers, evaluators, and policy makers. Feedback of the consultation and an exploration of possible concrete elements of FSDN will be discussed in a second workshop, planned for July 2021.

2. FADN for environmental and social sustainability assessment: a short literature review

FADN has been used as main source of information in several analysis performed at European, national, and regional level. Generally, FADN permits to evaluate and assess mainly the economic dimension of the sustainability while social and environmental aspects can be investigated only adding further variables to the FADN core. Several countries have already an extended data collection in their national FADN systems to cover sustainability issues (Vrolijk *et al.*, 2016).

For each farm in the sample, information is collected using a Farm Return, a questionnaire including around 1,000 variables according to the EU Regulation. Information is divided in categories: (i) physical and structural data; (ii) economic data; (iii) financial data. The Italian FADN includes more than 2,500 variables, exceeding the core EU FADN (Table 1) and showing a greater level of detail especially for the technical aspects of farm management. This wider informative background of the Italian FADN permits to perform several analyses which go beyond the only economic aspects.

Most environmental and social sustainability studies based on FADN have been made at territorial scale, developing analytical frameworks based on sets of indicators calculated for intra-region and national comparisons. A rich literature on sustainable indicators at farm level is described in Diazabakana

Table 1 - Quantitative assessment of informative contents in EU and IT FADN

Categories	**EU FADN**	**IT FADN**
Accounting records (*divided into 80 transactions in IT FADN*)	<20	30
Accounts managed directly by user	0	80
Types of machinery and equipment	0	300
Types of farm buildings	0	70
Types of soil (*physical characteristics and fertility*)	0	20
Arable and permanent crops (6,*800 cultivars in IT FADN*)	<100	380
Animal species and categories	<30	100
Types of crop products (*main and processed)*	<50	54
Types of livestock products (*main and processed*)	<10	35
Categories of technical inputs (*fertilizers, seeds, etc.*)	<25	110
Subsidy types (EU, National, Regional)	<300	500
Total Variables (approximatively)	1,000	>2,500

et al. (2014), classified according to their use (farm decision support, farm comparison, policy evaluation).

One of the first analysis has been performed by Andersen *et al.* (2007) around a set of farm management indicators based on the farming intensity in each European Member States. They considered bi-dimensional farming typology based on land use and intensity to evaluate the environmental performance of farms. Another contribution comes from Van Passel et al. (2007), who implemented an empirical model to measure farm sustainability using FADN dataset in a group of dairy farms in Flanders during the period 1995-2001. The sustainable efficiency is measured based on the "sustainable value added" already applied in other studies (Figge and Hahn, 2004). Boone and Dolman (2010) and Dillon (2010) give a measure of sustainability starting from FADN data for a Dutch fattening pig farm and in the Irish agriculture, respectively. Another interesting approach is presented by Reig-Martínez *et al.* (2011), which built up a composite indicator at farm level to assess social, economic, environmental issues, combining Data Envelopment Analysis and Multi-Criteria Decision-Making methods. Composite indicators to evaluate the sustainability of farms have been proposed also by Gómez-Limón and Sanchez-Fernandez (2010). Zahm *et al.* (2008) and Cadilhon *et al.* (2006) describe the extension and adaptation of the sustainability indicators in the IDEA (Indicateurs de Durabilité des Exploitations Agricoles) method (41 related to economic, environmental, and social aspects) to assess the sustainability of the main French types of farming. The set of indicators of IDEA were combined with information from the French FADN and Agricultural Census to develop de IDERICA method. The analysis highlighted the difficulty to calculate many of the original IDEA indicators and that the problems in the assessment of the social sustainability. The same difficulty is highlighted in the work of Sulewski and Kłoczko-Gajewska (2018) focused on a procedure for the estimation of the farm sustainability index integrating accountancy data with direct interviews with the farmers to cover the lack of social data in FADN. The need to enhance the social information in FADN emerges in Dabkiene (2016) that presents a sustainable use of FADN to cover the Sustainability Assessment in Food and Agricultural Systems (SAFA) subthemes. The analysis reveals a medium coverage of the SAFA environmental subthemes and a low coverage of social ones.

The need for monitoring and assessing sustainability at farm level led to the development of a common methodology for assessing the environmental impact of European Agri-Environment Schemes (AES). The Agri-Environmental Footprint index aggregates the measurement of agri-environmental indicators at farm level and has been used in combination with the UK FADN (Westbury *et al.*, 2011) to derive indicators of environmental performance in different farming systems and regions and to derive quantities of fertilisers used on farms by the total expenditure on fertilisers.

Several studies have been performed also in Italy. Trisorio (2004) assesses the sustainable development of the Italian agriculture suggesting a set of agri-environmental indicators and considering all the dimension of sustainability. Bodini *et al.* (2012) and Longhitano *et al.* (2013), evaluate the sustainability at farm level through the calculation of a composite index using as much as possible FADN database as main source of information and calculating the Sustainable Farm Index (SuFI) realised as an aggregation of data coming from a set of environmental, economic, and social indicators, ranking the farms to evaluate their potential role in the context of green-growth strategies.

As already mentioned, social sustainability based on FADN data is less frequently analysed because of the few specific variables collected inside the network that made possible only a synthetic assessment of this dimension of sustainability. An analysis in all the FADN European regions has been developed in Janiak *et al.* (2018) applying the Sustainable Value method to the 2004-2015 FADN database and using as input indicators the unpaid labour input, the paid labour input, the wages paid. Tantari *et al.* (2017) performed an analysis on off-farm incomes starting to the additional information collected in the Italian FADN regarding the farm's family in term of components, farm employment and off-farm incomes. For each family member, the income class, the income typology, and the economic sector of employment is identified. The aim of the analysis was the estimation of the total familiar income, as sum of farm and off-farm income and it has stressed the importance of the second category in the assessment of the farm income situation.

3. Strengthening the use of Italian FADN for the assessment of environmental and social sustainability at farm level

The Italian FADN is a sample survey that collects information over more than 11,000 agricultural holdings representing the different type of farming and economic dimension classes of the whole territory. The sample represents 95% of the Utilized Agricultural Area, 97% of the Standard Production, 92% of the Work Units and 91% of the Livestock Units. The first scope of the Italian FADN is the satisfaction of EU informative needs: data are transmitted to the European Commission mainly for the evaluation of the CAP measures and impacts. At National level, the FADN dataset has multiple uses: agricultural policy analysis, evaluation of the RD measures, the payment justification, etc. As previously mentioned, there is a difference between the FADN core and the Italian FADN in terms of number of information gathered at farm level. Beyond the highest detail of technical and economic data, more emphasis is given to the environmental and social aspects related to the farm management. It is highly likely that the current information content of Italian FADN may be able to cover the future need of the survey in terms of sustainability. However, there is room for improvement in terms of how the information is collected and how the quality of data can be improved. Moreover, the possibility to integrate the system with other administrative databases is considered a further element of enhancement.

The following paragraphs focus on the most important environmental and social variables included in FADN, what is currently collected and in what extent the quality of data could be improved. All the considerations came from an internal discussion of a working group established in CREA-PB including all the subjects involved in the survey (the staff involved in the collection, validation, transmission of data to EU Commission and in the FADN IT development and data management system).

3.1. *Environmental sustainability*

Environmental sustainability in agriculture is a very wide concept, declined in various aspects related to the contribution to climate change mitigation and adaptation, the production and use of sustainable energy, the efficient management of natural resources (water, soil, and air), the protection of biodiversity, etc. In agriculture, the sustainability is also linked to the emerging concept of sustainable food, resulting from the reduction of pesticide use, the limitation of antibiotics in livestock farming system, the enhancing of EU quality certification schemes (like organic labelling or territorial marks).

Gathering information on environmental variables is one important issue in FADN. Compared to the EU survey, the Italian system is characterized by a higher detail (Table 2). Italian FADN provides data about the water volumes of irrigation and fertigation as well as the unit of nitrogen, phosphorus, and potassium (NPK), for the farm as a whole and in the single production processes. Another important environmental information regards the indication of the toxicity categories for the crop protection products and some environmental characteristics of the farm management. Moreover, Italian FADN gathers more detailed information about the use and production of renewable energy.

Table 2 - Environmental variables in FADN: a comparison between EU and IT FADN

Environmental variables	**EU FADN**	**IT FADN**
Georeferencing farms	✓	✓
Irrigated UAA	✓	✓
Water volumes of irrigation and fertigation		✓
Amount of N, P and K used on the farm	✓	✓
Unit of N, P and K used in a single crop		✓
Use of crop protection products (*toxicity class*)		✓
Crops for energy use	✓	✓
Type of land use (*minimum tillage/no-tillage*)		✓
Cover crop (*e.g., date of seeding, date of harvest*)		✓
Environmental constraints – UE water directive	✓	✓
Environmental constraints – nature 2000 area (SPA-SCI)	✓	✓
Details on the use and production of renewable energy		✓

How these variables are collected and how their quality could be improved or integrated is a part of the discussion.

- *Water use*: information regarding water is considered crucial for the assessment of environmental sustainability and the estimation of water footprint. The Italian FADN collects several data such as cost, consumption, supply sources (basins, streams, groundwater, consortium network, etc.), uses (livestock, crops, other). Irrigable and irrigated area is also indicated. The volume of water distributed per cultivation and the irrigation period is an additional information. However, water volumes are not always easy to gather especially when the farm has not counters or other measurement systems. With this respect, the survey could be improved evaluating the opportunity of deriving the information from the water requirements of the irrigated crops. Otherwise, a targeted survey on a sub-sample (limited to the most important cultivations) could be defined.

- *Nitrogen, phosphorus, potassium (NPK) in fertilizers*: the quantity, cost, and title (in terms of FADN, when required) of around ten different types of fertilizers is an important information collected at farm level. In the Italian FADN the cost is also allocated among the different crops to calculate the gross margins. Regarding this procedure, the survey could be improved adding the allocation of fertilizers in terms of NPK quantity: it could permit an evaluation of the distribution of chemical elements per hectare and type of crop to perform spatial and temporal analysis of fertilization methods over time. The integration of this data with the nitrate vulnerable zones mapped at municipal level could be interesting for specific analysis.
- *Pesticides and crop protection products*: Italian FADN classifies several typologies of pesticides (around 10 including fungicide, herbicide, acaricide, plant growth regulator, insecticide), gathering information in terms of quantity and cost (the cost can be referred to the whole farm or allocated to the single production process). The active ingredients and the concentration are not gathered but the system requires the indication of the toxicological category. Although the importance to have this information, the collection is not always easy because of problems regarding the measurement unit and the toxicological category that sometimes can differ for the same product (depending by the formulation: powder, liquid, emulsion, etc.). Moreover, the knowledge of the treated area would require additional information because the data is referred to the total farm (Uthes *et al*., 2019). A possible way for overcoming these difficulties could be a provision of a database containing all the commercial products with the respective formulations, and their active ingredients. In this way, the quantity and cost will be gathered at farm level and the key information regarding the quality of pesticide could be derived by this integrative tool.
- *Soil erosion, organic matter, and soil management*: for each crop, Italian FADN indicates the type of land use (for instance tillage, conservative farming) but specific information regarding soil management is not collected despite the importance in terms of environmental sustainability. Including this data is difficult mainly because agricultural practices do not

fall within the scope of an accounting data network. However, it would be possible to investigate this aspect integrating FADN with other database or providing for a targeted questionnaire for an eventual sub-sample of farms.

- *Energy use and production of renewable energy*: this is a wide topic that concerns both consumption and production at farm level. On the consumption side, Italian FADN collects information about quantity and cost of motor fuel, heating fuel, and electricity. In addition, it is collected the typology such as gasoline, diesel, methane gas and so on. Regarding the production of renewable energy, the main source is indicated (solar, wind, biomass energy) together with the output in terms of quantity, revenue, and income.

3.2. *Social sustainability*

In the scientific community, sustainable agriculture is commonly examined regarding the environmental problems in terms of natural resource conservation or considering the need for more resource efficiency. More complicated is the assessment of the social dimension of sustainability: although the advance in this field (Janker *et al.*, 2019; Eizenberg and Jabareen, 2017: McKenzie, 2004), is not completely clear what this concept should entail, depending on different actors' interests and goals. Current research on the social dimension of sustainability addresses several fields, different levels and employs various conceptual approaches: development studies, political studies, project development, business, and management, etc. (a short literature review is described in Janker *et al.*, 2019). Moreover, farm sustainability assessment tools and scope of the analysis vary widely, indicating the need for a common understanding of the social dimension of sustainability in agriculture (Janker and Mann, 2018).

The main goal of a farm is the production and the income maximization even if farmers decisions are driven also by non-monetary issues including social benefits (Howley, 2015). While FADN permits easily to perform income or profitability analysis, social aspects are difficult to assess because EU Farm Return does not collect enough information suitable to be used for these purposes.

What kind of social relationship is possible to analyse within FADN survey? An interesting conceptual frame that could be adapted to this scope has been developed by Janker *et al.* (2018). According to this vision, the agricultural social system has its basis in the actors and their interactions: the central element is represented by all the stakeholders involved directly or indirectly with the agricultural processes, interacting in the farm sphere but also outside.

These interactions can change over time and can be divided in institutionalized interactions (specific relationships, contracts, partnerships, agreements, etc.) or institutional embedding (like norms, traditions, legal system regarding work and workers, etc.). There is a mutual influence among all the elements: some of them directly influence the agricultural production activities while others influence and are influenced by other systems.

This partition serves as a tool for the classification of the social data on farming collected by the Italian FADN and, eventually, for an additional (or parallel) data collection addressed to a more accurate social sustainability assessment.

In this model, the agricultural system is divided in two subsystems, internal and external.

The internal agricultural social subsystem is developed inside the farm and is described by all the data focused on the actors involved in the agricultural process: farmer, family members, employees, seasonal workers, etc. The external agricultural social subsystem is the surrounding system of social interactions that can influence directly or indirectly the farm. Individuals or companies connected with farm inputs, output, logistic, employment, advisory services, etc. have a direct influence and their interactions, being based on work aspects or monetary transactions, can be monitored with a data collection. Monitoring the direct influence of not-farming activities is more difficult: interactions with family members, friends, colleagues, organizations can influence the private life of the farmer and his/her family and, to some extent, contribute to the integration in the local community, considered an important factor of well-being (McManus *et al.*, 2012) and an indicator of social sustainability.

Indirect influence on the agricultural social system is exerted by all the mechanisms acting as farmer's motivation, focused on the expectations and on local institutions norms and values: behaviour to avoid specific sanctions, attentions to the food security and environment and not only to profit maximization, attention to the animal welfare and food quality, understanding of the choice of food products or the reputation of specific production systems, etc. All these aspects cannot be directly monitored in FADN, but their understanding require the evaluation of the general territorial system in which the farm operates.

Having in mind this framework of the social aspects influencing the agricultural activity, is possible to define and select quantitative indicators that refers to social sustainability and that can be collected within FADN (or specific farm surveys, like in Gaviglio *et al.*, 2016). In the following points, the social data are described, grouped by sub-theme, together with a consideration about the need and opportunity to strengthen the survey in future.

- *Description of farmer and family members*: the internal agricultural social subsystem is defined first by the actors directly involved in the production. The Italian FADN collects information regarding the relationships among all the family farm members and this permits to describe specific characteristics of the farmer, the role (he/she could be employed full-time or part-time; he/she could be retired; he/she could work alone in the farm or not, etc.) and the role of family members (common or specialized worker, manager, not employed in the farm activities, etc.). They can be employed in the farm at full-time or occasionally (harvesting period, for instance) or have an off-farm income. Age is also indicated for all members, and this should be an indicator for the generational renewal analysis.
- *Ownership*: the bonds between farmer and farm can be additionally described with this information regarding the type of ownership, the legal status, the level of liability of the holder, the share of rented agricultural area on the total, the rents paid, etc.
- *Gender balance*: gender is recorded for holder/manager, all the family members, other employees, and seasonal workers (as number of women employed seasonally out of the total). It is an information useful to perform comparative analysis for the profitability in farms run by women versus farms run by men or to better understand the importance of the women component in specific territories or type of farming.
- *Agricultural training*: it is another important variable suitable to be used in the description of the farmer characteristics but also as input to investigate the external agricultural social subsystem. Training is a key aspect for the growth of the agricultural sector and the requirement of high-profile skilled job in the farm activities can be considered as an important driving force of the development and innovation process of the territory. Italian FADN collects information regarding the qualification of the farmer and family members in terms of general level of education and this is not completely aligned with the EU requirements, based mainly on the distinction among practical experience only, basic training and full agricultural training. This last aspect is very interesting in terms of social sustainability because gives a measure of the territorial capacity to influence skills and expertise of farmers. The identification of targeted agricultural training and the subjects covered could be an additional indication of the efficiency of the local institutions. This variable is under revision, and it will be improved in future.
- *Advisory services*: the cost for advisors is gathered (as required by EU Regulation) while the information about the kind of advice is not specified. It could be added in the survey as an indicator of the relationship between internal and external agricultural subsystems but also as an indicator of the

local capacity to meet the farmer needs not only in the traditional fields (like crop management or animal husbandry) but also in advice relate to innovation, environmental protection, social aspects, commercialization, etc. Moreover, it should be used as indicator in case of impact analysis of some RDP measures.

- *Interaction with local Organizations, social involvement, and responsibility*: cooperation, association, social involvement in local groups, memberships in local organization, consortia or other production structures are considered as important indicators of human development in rural areas. In the Italian FADN there is not a specific investigation and only a minimum set of qualitative data are collected with regard the affiliation to local Producers Organizations or consortia. The survey could be enhanced obtaining information on these aspects from the whole sample.
- *Labour input and costs*: number of hours, number of workers (in term of persons and Annual Work Units), wages and social security costs for paid labour are collected by the Italian FADN. The ratio between unpaid and paid labour or the regular versus causal labour is an indicator of the work patterns.
- *Source of income*: the farm income can be seen as the sum of agricultural income, income coming from other gainful activities (OGA, described in detail) related to the holding and off-farm income (not required by EU Regulation). All the information regarding these aspects is collected by the Italian FADN and often is considered in the analysis based on the diversification and multifunctionality of farm activities.
- *Production quality, certifications, retail channel*: the relationship between producers and consumers can be identified as an external interaction having direct and indirect influence on the farmer behaviour. Traditions, local economies, trust in producers, etc. are important elements recognized as social attributes by the literature (Bessiére, 1998; Seyfang, 2006; Gaviglio *et al*., 2016). The presence of certifications and the retail channel chosen by the farm also give indications about the link between the farm and the territory. Italian FADN collects data on several kind of certifications (not only the territorial marks like PDO, PGI, TSG) but also on organic agriculture and different other kind of certification (included the environmental ones). Regarding the retail channel, this information is collected but it must be improved adding to the traditional channels already detected, further systems like short food supply chain, direct sales, online sales, canteens, restaurants, ethical purchasing groups, etc.
- *Connectivity and information systems*: the future of agriculture is in the connectivity, ability to share information and data across devices, improvement in the information system, etc. These elements will serve to increase the capacity of farmers in increasing their productivity but also in

strengthening the interaction with social network, extension and advisory services operating agricultural technology. Italian FADN does not collect this information, highly recommended for the future implementation.

Final remarks

The launch of a Farm Sustainability Data Network (FSDN), more oriented to incorporate the three dimensions of sustainability, will permit to reach several objectives partially covered by the current accounting system. At EU level, it will permit to increase the environmental and social information regarding the farm activity and, to some extent, to analyse synergies and/or trade-offs between economic and environmental outcomes of farming practices. If well developed, FSDN will provide data-based discussion tools for farmers and advisors, helping them to become more sustainable by identifying bottlenecks and best practises. Finally, it will be a key data source to monitor the progress towards Farm to Fork and Biodiversity targets.

FSDN principles move in the same direction of FADN: the new survey will maintain and improve the current role of FADN as the only source of harmonized microeconomic farm level data in the EU and as the reference source of data for income related Performance Monitoring and Evaluation Framework (PMEF) indicators. By adding the environmental and social dimension of sustainability, FSDN will reinforce the analytical and political relevance of FADN: an enhancement of the use of data in farm advice benchmarking, training and innovation could reinforce farmer's incentives to participate in FSDN. Moreover, it will improve linkages with existing data collections adding new variables not available elsewhere.

However, the shift into a more detailed system as FSDN has also some constraints. The excessive increase of variables could result in collapsing of the whole idea of FSDN. Particular attention must be paid to (i) farmers' willingness to participate (already now countries are facing serious problems in recruiting enough farms for participation in FADN, particularly bigger farms); (ii) resistance by Member States (it will be important to involve policy makers from agricultural and environmental ministries and organizations); (iii) additional resources: requirements in terms of changes of the IT infrastructure, data collection and verification processes will take additional budget and staff, new resources and new ways of collecting data in Member States.

Theoretically, the current Italian FADN system appears to be more oriented to satisfy some environmental and social informative need respect to the EU FADN. However, having the Member States the faculty to add the survey of specific variables, further efforts could be done to enhance the actual system. This can be realized according to several hypothesis:

- adding (or improving) a core set of new variables to the Italian Farm Return gathered every year to all the farms participating in FADN;
- defining supplementary modules focusing on specific aspects identified in the survey, addressed to the whole FADN sample or selecting a sub-sample (one specific agricultural sector, farms located in mountain, farms with OGA, etc.) depending on the scope of the analysis;
- selecting satellite samples focusing on specific aspects not traditionally covered by the FADN topics.

One important methodological aspect related to the future survey will be the opportunity to integrate the collection in the current FADN structure or to opt for supplementary modules or sub-samples. Advantages and disadvantages are resumed in Table 3.

Table 3 - Advantages and disadvantages of collecting sustainability data in FADN or in a supplementary module or separate sample

Integrated data collection in the current FADN scheme	**Supplementary module/separate sample**
(+) Trade-off between objectives/ indicators	(+) Selectiveness and possibility to optimise the survey design for specific variables
(+) Integrated policy analysis	(+) Reliability: more accurate information and more reliable estimates
(+) Use of existing procedures and data management	(–) No link with economic performance or policy measures in case of supplementary modules on satellite samples
(–) Increased complexity of data collection (number of variables, data collectors' skills)	(–) Time and resources to establish supplementary modules
(–) Possible need to reconsider fields of observation and complication of the sample design because of a wide variety of objectives	(-) Availability of data collectors to gather further information
(–) Need for re-adjusting current systems and working processes (online tools, supplementary modules)	(–) Costs of the supplementary modules
(–) Higher cost of the survey	

Source: Vrolijk (2016), adapted.

The supplementary modules will require an IT adaptation. The software GAIA, ought to become an online tool (GAIAWeb), will include the new variables and a parallel upgrading of the data check and validation methodologies. The annual training for data collectors will be targeted to include the environmental and social aspects of farm activity. The economic consequences of these changes should be also evaluated: most likely the integration of variables, modules or satellite samples will require a higher cost for the survey.

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Economia agro-alimentare /
Food Economy

An International Journal on Agricultural and Food Systems

Vol. 23, Iss. 3, Art. 5, pp. 1-24 - ISSN 1126-1668 - ISSNe 1972-4802
DOI: 10.3280/ecag3-oa12772

Estimation of the impact of CAP subsidies as environmental variables on Romanian farms

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Abstract

Romanian agriculture is characterised by the presence of small farm enterprises, with an average value of land capital of less than 5 hectares in more than 95% of cases. The aim of this research was to assess the level of technical efficiency in farming through a non-parametric approach such as the Data Envelopment Analysis (DEA), and also to estimate the impact that financial subsidies allocated under the first and second pillars of the Common Agricultural Policy (CAP) have had on the technical efficiency. In the application of this analysis, these two inputs have been considered as environmental variables in order to evaluate their effect in fostering the technical efficiency using a two-stage DEA method. The results have revealed the pivotal impact of financial subsidies disbursed through the first and second pillars of CAP in enhancing technical efficiency in the Romanian farms included in the FADN dataset. In contrast, the subsidies disbursed under only the second pillar of the CAP in the framework of rural development have not been found to have had any discernible effect on the technical efficiency of Romanian farms. The novelty of this quantitative approach in the estimation of technical efficiency lies in its focus on the role of environmental variables as drivers in affecting the technical efficiency of farms, defining, in addition, how important they are in addressing efficiency and in shifting enhancing the function of technical efficiency on farms as well. Some conclusions were drawn: it is important to increase the endowment of subsidies for rural development and as well as

Article info

Type:
Article
Submitted:
07/04/2021
Accepted:
30/06/2021
Available online:
12/01/2022

JEL codes:
Q12, Q18, R15

Keywords:
Data Envelopment Analysis
Technical efficiency
Separability test
Rural Development Programme
FADN

Managing Editor:
Lucia Briamonte,
Luca Cesaro,
Alfonso Scardera

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decoupled payments in order to raise the level of technical efficiency in Romanian farms. At the same time, the findings suggest the need for Romanian farmers to reduce the level of certain inputs, such as labour, on the one hand, while on the other, increasing the dimension size of farms in terms of land capital and encouraging greater investment in labor-saving technology, even if significant imbalances remain between different Romanian regions, both in terms of the level of technical efficiency achieved and also in terms of output yield, and in the endowment of land capital and other assets.

Introduction

Over the last 20 years, the Common Agricultural Policy (CAP) has undergone profound and structural changes necessitated by ever more severe budgetary constraints following international agreements in WTO trade negotiations and the various phases of enlargement of the European Union that have occurred since the early 2000s. At the same time, public opinion has modified its attitude to farmers, who are now seen to be one of the main bastions for the protection of the environmental and drivers of economic development for rural areas. All these economic and social constraints have radically modified what is one of the oldest policies of the European Union. Meanwhile, for the current seven-year period of Common Agricultural Policy planning for 2021-2027, partly in view of the possible phasing out of direct payments from 2028, and as a consequence of the economic crisis brought about by the Covid-19 pandemic, the European Commission has introduced strictly demanding strategies for European farming that have led to a complete overhaul in the allocation of European Union funding for different economic and productive sectors (Beluhova-Uzunova *et al.*, 2017; Galluzzo, 2020a; 2021). Over the years, it is clear that a new strategy for addressing the primary sector has developed, which has seen the CAP transition from being a commodity-specific policy based on a high level of price support for agricultural commodities and by decoupled payments and other direct payments, to being a farmer-specific policy that is addressed, primarily, to protecting the environment as well as to stimulating greater multifunctionality in farms as well as in the wider rural area through funding made available under the second pillar and the LEADER initiative.

Since the launch of the Agenda 2000 project in the early 2000s, the structure of the Common Agricultural Policy has completely changed in shape and function, and is now based on two pillars, each with different and specific targets of action, namely supporting for farmers, through decoupled payments and various direct grants, and encouraging rural development in a holistic model of socio-economic growth for rural areas. The first pillar, through such instruments as the Single Payment Scheme (SPS) established in 2005, and the Single Area Payment Scheme (SAPS), is primarily addressed to farmers, indirectly supporting farmers' productions through decoupled payments, whilst the second pillar is focused on rural areas, aiming to improve living conditions in rural territories through innovative bottom-up initiatives such as the LEADER programme (Galluzzo, 2020a). The purpose of the second pillar is to stimulate investments in structural and productive infrastructure while also supporting, through specific financial measures, the diversification of rural areas (Galluzzo, 2020b; 2020c). In this light, the second pillar is fundamental to disadvantaged and scarcely populated rural areas characterised by small farming enterprises, as in many parts of Romania, which are at severe risk of depopulation owing to demographic ageing processes and permanent emigration encouraged by a scarcity of working opportunities (Galluzzo, 2018; 2020b). In fact, lots of Romanian farms have got modest endowment of land capital which is lower than 5 hectares in the hands of aged farmers; hence, the CAP subsidies are fundamental in increasing labour saving investments, stimulating a generational turn over and improving training and new skills in farmers increasing the technical efficiency. Consequently it is fundamental to investigate in depth if the Common Agricultural Policy subsidies are able to increase the technical efficiency in Romanian farms. In particular, the novelty of this study is to define which subsidies, between decoupled aids, directs payments or financial supports in investments and in on farm productive diversification, are more adequate in improving the technical efficiency in farms considering the financial subsidies as an environmental exogenous variable able to act on the efficiency in farm.

One of the main differences between the two pillars lies in the allocation of financial resources (Galluzzo, 2020a). In fact, the total amount paid in subsidies under the second pillar of the Common Agricultural Policy is significantly lower than that paid under the first pillar (Galluzzo, 2016; 2019a; 2019b; 2020b; 2020c; Stanciu, 2017), which corroborates the hypothesis that the CAP is a crystallised policy able to promote an indirect economic development through the first pillar while also encouraging greater diversification through financing made available in the framework of the Rural Development Programme.

In the process of the European Agricultural Fund for Rural Development (EAFRD) programming have been defined some selection criteria of the measures in the Rural Development Programme considering as constraints and criteria of selection of measures of financing the typical features of the Romanian agriculture such as the aging of farmers, the age of the entrepreneurs, the farm fragmentation, in particular in some counties close to Moldavian area, the clima protection aspect, the role of new young farmers in the management of farms, sustainable development, innovation and training of farmers, and the cooperation among EU countries with LEADER initiatives. Focusing the attention to the European Agricultural Guarantee Fund (EAGF) some criteria of selection in financed measures have been focused on investments in job creation, innovation in fruit sector, actions in supporting agro-food marketing, ecosystem services and providing in basic services in rural areas.

1. Background

The productivity of farms can be simply expressed as the ratio between the value of the output and the value of the inputs used in the productive process, without taking other factors into consideration (Osman & Anouze, 2014). It follows, then, that technical efficiency is the ability of an enterprise to obtain an optimal level of output using a given input (Farrell, 1957; Coelli *et al.*, 2005; Galluzzo, 2020a).

In general, the main elements used in estimating the technical efficiency (TE) of farms and in assessing the impact of financial subsidies allocated under the Common Agricultural Policy (CAP) have been assessed considering different constraints able to influence the efficiency score, such as the dimension of farms, the level of the farm's income, and the degree of socio-economic sustainability (Galluzzo, 2013; 2020a; Latruffe *et al.*, 2016; Latruffe *et al.*, 2017; Minviel & Latruffe, 2017; Garrone *et al.*, 2019). Various researchers, including Garrone *et al.* in 2019, Minviel and Latruffe in 2017, and Latruffe *et al.* in 2017, have previously conducted complete and exhaustive bibliographic analysis of the role of technical efficiency and financial subsidies allocated by the European Union, comparing different studies and European countries. These authors have deeply investigated the role of subsidies and agricultural productivity in the EU through the most recent literature studies related to technical efficiency.

Decoupled payments act predominately on the level of a farmer's income through the dimension of the farm in terms of its endowment of land capital, and this has encouraged an increasing demand for land capital (Bartolini & Viaggi, 2013; Galluzzo, 2020a) that is also aimed at reducing the inefficiency in small farms. In relation to other European countries, recent studies have shown that subsidies can act on the technical efficiency and also on the levels of technology utilised (Latruffe *et al.*, 2017; Kumbhakar & Lien, 2010). Summing up, the research outcomes have underlined either a null or fairly minimal impact of payments allocated under the second pillar to disadvantaged rural areas (Baráth *et al.*, 2018; 2020; Nowak *et al.*, 2015; Rudinskaya *et al.*, 2019; Garrone *et al.*, 2019; Galluzzo, 2020a; Czyzewski *et al.*, 2017). As such, it is difficult to find a univocal interpretation of the impact of CAP subsidies on farms. Furthermore, it is hard to assess if there is a correlation between technical efficiency, public financial support for agriculture, and employment opportunities in rural areas (Petrick & Zier, 2011; Galluzzo, 2019a).

As mentioned above, a wide review of the available literature in the field of technical efficiency has identified many studies that have investigated the effect of financial subsidies allocated through the Common Agricultural Policy in depth through a quantitative approach, predominately using Data Envelopment Analysis (DEA) as well as Stochastic Frontier Analysis (SFA), the findings of which reveal a wide disparity in the impact they have had on the technical efficiency of farms in different European countries (Garrone *et al.*, 2019; Minviel & Latruffe, 2017; Latruffe & Desjeux, 2016; Galluzzo, 2016; 2020a; Forleo *et al.*, 2021; Nowak *et al.*, 2015; Laurinavicius & Rimkuviene, 2017; Czyzewski *et al.*, 2017; Gorton & Davidova, 2004). Several studies have pointed out that other variables influencing the technical efficiency, such as the level of the farmer's knowledge, can increase the farm's technical efficiency and economic performance (Manevska-Tasevska, 2016). Other authors have assessed the efficacy of financial subsidies allocated through the CAP in reducing imbalances between farms and territories through stimulating greater innovation in technology and reducing the technological divide on one hand, while also increasing the level of technical efficiency on the other (Baráth *et al.*, 2020; Zhu & Lansink, 2010; Ayouba *et al.*, 2017; Gorton & Davidova, 2004).

Several scholars have argued that financial support allocated under the first and second pillars of the CAP has reduced the need for farmers to improve their economic performance, level of technical innovation, and technical efficiency, even if the effect of decoupled payments on the farm's technical efficiency is ambiguous, being so strongly influenced by the farm's productive specialisation, and by the type of the subsidy disbursed, for example decoupled or direct, which can have various distorting effects on farmers' technical efficiency, innovation, and productivity (Mennig & Sauer, 2019; Garrone *et al.*, 2019; Latruffe *et al.*, 2017; Galluzzo, 2016; 2019a; 2020a; Nowak *et al.*, 2015; Swinbank, 2008; Zhu & Lansink, 2010; Rude, 2008; Ciaian & Swinnen, 2006; Ciaian *et al.*, 2014; Rizov *et al.*, 2013).

Von Witzke and Noleppa argued in 2007 that direct payments to German farms have had an unequal impact on smaller-sized farms, but that they have had a generally positive impact on farms located in disadvantaged rural areas. In contrast, other scholars addressing their field of study to new member states of the European Union have found a null or negative impact of subsidies allocated under the CAP on the general level of technical efficiency (Galluzzo, 2020a; Von Witzke & Noleppa, 2007; Baráth *et al.*, 2018; 2020; Nowak *et al.*, 2015). This last aspect has been found to be particularly true in farms located in mountainous and disadvantaged rural areas (Rudinskaya *et al.*, 2019; Baráth *et al.*, 2018; Galluzzo, 2016; 2019a; 2020a). However, other studies have underlined that there is a significant but modest nexus between financial support provided under the CAP and the economic development of rural areas, owing to the complexity and the different socio-economic peculiarities of the rural areas in EU countries (Shucksmith *et al.*, 2005; Crescenzi & Rodriguez-Pose, 2011; Galluzzo, 2016; 2019a).

More recent studies have investigated the impact on technical efficiency of decoupled payments and other financial support allocated in rural areas through the framework of the second pillar of the CAP in France and in some other European countries (Latruffe & Desjeux, 2016; Latruffe *et al.*, 2017; Minviel & Latruffe, 2017). According to these latter authors, research findings have found different effects in function of farms' productive specialisation. Indeed, a negative effect of investment subsidies on technical efficiency has been assessed in farms specialising in beef production while, in contrast, a generally positive effect of production subsidies has been found in farms specialising in field crops and dairy (Latruffe & Desjeux, 2016; Latruffe *et al.*, 2017; 2016; Minviel & Latruffe, 2017). Furthermore, these studies have underlined that rural development subsidies such as Less Favoured Areas (LFA) payments and agri-environmental payment schemes have had no discernible effects on technical efficiency in investigated farms (Galluzzo, 2020a; Latruffe & Desjeux, 2016; Latruffe *et al.*, 2017). On the contrary, studies carried out in new member states of the European Union have demonstrated a pivotal role of subsidies allocated under the second pillar of the CAP to farms, with the exception of LFA subsides, which had no impact (Baráth *et al.*, 2018; Galluzzo, 2020a; 2020b; 2019a).

In the available literature, there are not many studies aimed at estimating the impact of financial subsidies allocated under the first and second pillars of CAP to farmers in a two-stages methodology based on the non-parametric approach using Data Envelopment Analysis (Horvat *et al.*, 2019; Gutiérrez *et al.*, 2017; Forleo *et al.*, 2021; Gutiérrez & Lozano, 2020; Todorović, *et al.*, 2020). In the two-stages DEA approach proposed by Simar and Wilson in 2011 and 2007 and Daraio *et al.* in 2018, the technical efficiency has first been estimated through the DEA approach and then, in the following second stage, the results of the DEA have been correlated to certain environmental variables, such as the financial subsidies allocated under the first and second pillars of the CAP, which are considered as environmental variables able or not able to act on the technical efficiency score.

The main purpose of this study was to assess, in all Romanian farms, the impact of financial subsides allocated under the first pillar of the CAP, such as through decoupled payments and direct payments, and the second pillar of the CAP, through the Rural Development Programme, on the technical efficiency of farms, considering these subsidies as environmental variables correlated to the technical efficiency as estimated through the DEA approach in the first stage of the investigation. The element of innovation represented by this approach lies in the attempt to assess if those financial subsidies have influenced the technical efficiency as environmental variables, hence, by this two-stages DEA, it is possible to understand their role and how and if they should be implemented in the financial allocation to farmers. The main policy implications are the opportunities it gives policy makers to implement their allocation of funding, understanding the effect that first and second pillar subsidies and payments have on the technical efficiency of farms.

2. Materials and methods

In the literature, there are two different methodologies for assessing the level of technical efficiency in farms, one through a parametric or stochastic modelling (SFA), and the other through a non-parametric modelling, using the Data Envelopment Analysis (DEA) method (Farrell, 1957; Lovell, 1993; Coelli *et al.*, 2005; Battese & Coelli, 1992; 1995; Kumbhakar *et al.*, 2015; Aigner *et al.*, 1977; Cooper *et al.*, 2007). The SFA requires a well-defined function, such as the Cobb-Douglas, a logarithmic function, or the translog, and other a priori specifications in the model in terms of inputs and outputs, and their transformation (Coelli *et al.*, 2005; Lovell, 1993; Aigner *et al.*, 1977). In contrast, the DEA estimates multiple inputs and multiple outputs without the requirement for defined functions of production and other a priori specifications in the model (Coelli *et al.*, 2005; Bravo-Ureta & Pinheiro, 1993; Galluzzo, 2019a; 2019b; 2020a).

In this paper, the DEA approach has been used in an input-oriented variable returns to scale (VRS) model with the aim of minimising the inputs in each Decision Making Unit (DMU) of observation, which are the Romanian farms included in the Farm Accountancy Data Network (FADN) dataset (Galluzzo, 2013; 2015; 2019a; 2020a; 2020c). The sample is made up of farms from each of the 8 Romanian regions over a 12-year period of observation, from 2007 to 2018. As proposed by both Charnes *et al.* (1978) and Banker *et al.* (1984), the Data Envelopment Analysis model assumes certain constraints, namely that there are n DMUs which produce a well-defined quantity s of output y in such a way that $y \in RS^{+}$ by using several m inputs combined in a multiple arrangement and in combination of $x \in R^{+}$ (Galluzzo, 2019b; 2020a; Cooper *et al.*, 2007).

According to the methodological assumptions proposed in literature by different authors such as Charnes *et al.* (1978), the technical efficiency of each DMU can be estimated by solving a linear programming problem aimed at minimising, in an input-oriented approach, the level of inputs used in the production process in the dual forms (Charnes *et al.*, 1978; Banker *et al.*, 1984; Coelli *et al.*, 2005; Bravo-Ureta & Pinheiro, 1993; Battese & Coelli, 1992; Galluzzo, 2020a; 2019b; 2013; Cooper *et al.*, 2007), that can be expressed as:

$$\min \theta_k^c - \varepsilon\left(\sum_{i=1}^{s} S_i^- + \sum_{r=1}^{m} S_r^+\right) \qquad (1)$$

$$s.t.\ \sum_{j=1}^{n} \lambda_j\ x_i\ + S_i^- = \quad \theta_0\ x_{ik}\ ,\ i = 1, 2 \ldots, m,$$

$$\sum_{j=1}^{n} \lambda_j\ x_i\ + S_i^- = \quad \theta_0\ x_{ik}\ ,\ i = 1, 2 \ldots, m, \qquad (2)$$

$$\sum_{j=1}^{n} \lambda_j\ y_{ij}\ - S_r^+ = y_{rk}\ ,\ r = 1, 2 \ldots, s, \qquad (3)$$

$$\theta_k^c, \lambda_j, S_i^-, S_r^+ \geq 0,$$

where λ is a semi-positive vector in R^k.

For every Decision Making Unit (DMU), an estimation has been made of θ, which is the level of technical efficiency. A value which is equal to 1 implies the optimal combination of inputs and output, and so a minimising of the costs; ε is a non-Archimedean infinitesimal, proposed by Charnes *et al.* in 1978, able to overcome some difficulties linked to testing multi-optimum solutions in the model of solving the minimisation problem; and λ is a convex coefficient in the input x in each DMU_j producing a level of output *y* in the farms *j* (Coelli *et al.*, 2005; Battese & Coelli, 1992; Galluzzo, 2020). Meanwhile, S_r^+ and S_r^- are non-negative output and input slacks; thus, if θ is equal to 1 and all input and output slacks are equal to zero, the DMU is technically efficient (Charnes *et al.*, 1978, Banker *et al.*, 1984; Coelli *et al.*, 2005; Battese & Coelli, 1992). In contrast, as the above-mentioned authors proposed, if θ is not equal to 1 and all input and output slacks are different to zero, this implies that there is an inefficient use of resources as inputs for the amount of output produced by that DMU.

The general aim of the estimation of technical efficiency is to assess the distance of a hypothetical function of production from the frontier, hence, it is an assessment of an inefficient use of inputs, consequently defining an index of technical inefficiency (Bielik & Rajcaniova, 2004; Galluzzo, 2013; 2016a; 2017; 2018a). Summing up, farms located along the hypothetical function of production are efficient, whilst those located outside this frontier are inefficient, due either to an excess of input, in the case of the input-oriented approach, or a shortage of output in the case of the output-orientated approach (Galluzzo, 2015; 2016a; 2017). The value of technical efficiency should be greater than 0 and lower than 1, which is the frontier of optimal technical combinations of input-output, representing a well-defined use of technology by the DMU (Coelli, 1996; Coelli *et al.*, 2005; Galluzzo, 2013; 2015; 2016; 2017). Through either a decrease in inputs, in the input-oriented model, or an increase in output, in the output-oriented model, it is possible to move DMU_j from an inefficient position to an efficient one, so increasing that DMU's technical efficiency score (Galluzzo, 2020a; 2019; 2017; Latruffe *et al.*, 2017).

In this paper, the technical efficiency in all Romanian farms included in the FADN dataset over the period 2007 to 2018 has been estimated using a non-parametric model applied to specific assumptions in a variable return to scale (VRS) input-oriented model (Farrell, 1957; Battese & Coelli, 1992; 1995; Coelli *et al.*, 2005) using the R, Stata and Xlstat software. In order to make the dataset homogenous, the effect of inflation has been removed; in fact, the input and output variables in the dataset, expressed in Euros, have been deflated using the Eurostat deflator and all data are in constant values, referred to the year 2010.

The first step of the research was to select the input and output variables and the environmental variables, making reference to previous published studies in relation to DEA and technical efficiency available in the literature (Forleo *et al.*, 2021). The input variables selected for the assessment of technical efficiency in the DEA input-oriented approach were: land capital, measured in terms of usable agricultural areas (UAA); labour, measured in man hours and relating to both family members and hired labour; specific costs, comprising seeds, fertiliser, pesticides, and other items; total farming overhead costs or, rather, supply costs linked to production activity but not linked to specific lines of production; and assets. The output comprises the total value of the production yield of farms, expressed in Euros and referred to the year 2010. The environmental variables (Z) selected for this research were decoupled payments and direct payments allocated under the first pillar of the CAP, and financial subsidies disbursed by the Rural Development Programme.

With the purpose of assessing whether certain environmental variables, such as financial subsidies allocated under the first and second pillars of the CAP, have acted on technical efficiency in the DEA, the research has adopted the approach proposed by Simar and Wilson in 2007, called two-stage DEA (Simar & Wilson, 2011; 2015; Daraio & Simar, 2005; Daraio *et al.*, 2015;

2018; Bădin *et al.*, 2012). The estimation of technical efficiency in the two-stage DEA approach has been made using the R software package rDEA, with the aim of producing bias-corrected efficiency scores in input-oriented DEA models, using the above-mentioned environmental exogenous variables in a bootstrap replication in the first and second loop.

In any case, in order to estimate if the environmental variables (Z) have had some effect on the overall technical efficiency of the farms included in the FADN sample and previously estimated by the DEA, the separability test proposed in the literature has been applied (Simar & Wilson, 2007; 2011; 2015; Daraio *et al.*, 2015; Daraio & Simar, 2005; Kourtesi *et al.*, 2012; Wang & Schmidt, 2002). The environmental variable (Z) is a vector able to act on the input and output variables and on the production function, changing its shape and affecting also the distribution of the inefficiency scores not dependant on the environmental variable (Bădin *et al.*, 2010; Kourtesi *et al.*, 2012; Wang & Schmidt, 2002). Under the assumption of separability, the environmental variables do not have any effect. In contrast, if the assumption of separability decays, the impact of the environmental variables influences the level of efficiency (Kourtesi *et al.*, 2012). According to these authors, it is possible to assess the separability using the test proposed by Daraio *et al.* in 2015, based on the distance between the efficiency boundaries, once with the effect of the environmental variables and another without any effect of the environmental variables. The null hypothesis is that, in the case of separability, the two boundaries are the same (Kourtesi *et al.*, 2012; Wang & Schmidt, 2002; Bădin *et al.*, 2010; Simar & Wilson, 2007; 2015; 2011; Daraio *et al.*, 2015; Daraio & Simar, 2005) estimated as Daraio *et al.* (2015) proposed, by:

$$\hat{\tau}_n = [\textstyle\sum_{i=n}^{n}(\hat{D}'_{\mathrm{FDH,i,n}})(\hat{D}_{\mathrm{FDH,I,n}})]/n \geq 0 \quad (4)$$

where n is the sample size

$$\hat{D}_{\mathrm{FDH,I,n}} = Y_i(\hat{\lambda}_{\mathrm{FDH,i,n}}(X_i,Y_i) - \hat{\lambda}_{\mathrm{FDH,i,n}}(X_i,Y_i \mathrm{I} Z_i)) \quad (5)$$

A large value of t rejects the null hypothesis of separability, meaning that the selected environmental variables do have an effect.

For the purposes of this research, the impact of different environmental variables has been estimated on the basis of four hypotheses. In the first hypothesis, the impact of three environmental variables has been estimated, namely decoupled payments and direct payments allocated under the first pillar, and financial subsidies allocated under the second pillar of CAP. In the second hypothesis, the impact of two environmental variables has been tested: direct payments allocated under the first pillar of CAP, and financial subsidies allocated under the second pillar of CAP. The third hypothesis has estimated the effect of decoupled payments and direct payments allocated under the first pillar of CAP. Finally, the fourth hypothesis has taken into account only the effect of financial subsidies allocated through the Rural Development Programme in the framework of the second pillar of the Common Agricultural Policy. All four hypotheses have been tested using the global separability test proposed by Daraio *et al.* in 2015 with a level of a 0.05.

3. Results

Over the period of investigation, the research findings have underlined a modest land capital endowment in all Romanian regions which is, on average, close to two-thirds less than the average value of 15 hectares assessed through Eurostat for the European Union as a whole (Table 1). This has had some implications on the total produced output in the farms included in the FADN sample, and on the level of assets and investments in farms. Romanian farms that are included in the FADN dataset have shown a remarkable demand for labour capital, with an average of over 3,000 hours, due to a low level of investment in machinery and to the division of the land into small and scattered plots, which are more labour-intensive. A significant incidence of financial aid allocated by the Common Agricultural Policy can be ascribed to

Table 1 - Descriptive statistics in all Romanian farms included in the FADN dataset over the period of investigation

	Labour	**UAA**	**Total output**	**Specific costs**	**Total farming overhead costs**
Mean	3,243.49	10.96	16,212.94	4,980.39	2,589.39
St. deviation	1,032.31	5.07	10,122.45	2,461.80	1,381.31
Median	3,196.70	9.84	14,570.48	4,843.32	2,344.51
	Assets	**Total subsidies**	**Direct payments**	**RDP**	**Decoupled payments**
Mean	57,185.20	2,205.27	2,042.09	89.85	1,334.49
St. deviation	67,340.33	1,330.88	1,304.99	169.21	1,037.55
Median	43,451.64	1,932.50	1,709.00	15.50	1,055.00

Source: author's own elaboration on data available at https://agridata.ec.europa.eu/extensions/FADNPublicDatabase/FADNPublicDatabase.html.

the first pillar, notably in terms of decoupled payments, whilst the total value of financial subsidies allocated under the second pillar, specifically through the Rural Development Programme, averages less than 100 Euros per farm.

Table 2 - Descriptive statistics in all Romanian regions in input and output variables used in the analysis of technical efficiency dataset

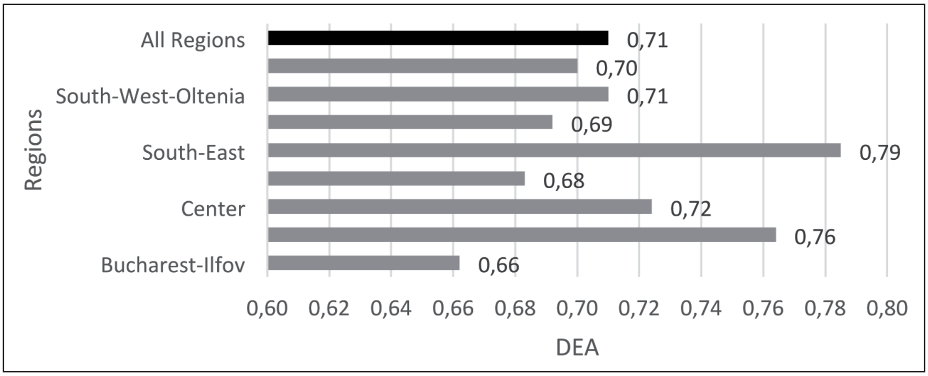
	Labour	UAA	Total output	Specific costs	Total farming overhead costs	Assets	Total subsidies
				North-East			
Mean	3,122.55	7.57	10,608.33	3,685.15	1,693.10	26,941.37	1,320.75
St. deviation	1,103.13	1.94	2,934.43	1,228.45	411.82	5,094.55	622.95
Median	2,784.90	7.19	10,681.12	3,400.96	1,749.90	26,326.33	1,159.50
CV	0.35	0.25	0.27	0.33	0.24	0.18	0.47
				South-East			
Mean	3,445.04	15.17	17,994.89	5,900.14	3,037.26	43,711.75	2,885.66
St. deviation	565.41	4.06	5,691.55	2,027.42	660.94	14,276.44	1,245.40
Median	3,359.99	14.53	18,844.63	5,501.96	3,030.57	41,575.65	2,457.00
CV	0.16	0.26	0.31	0.34	0.21	0.32	0.43
				South-Muntenia			
Mean	3,255.28	11.38	15,877.75	5,703.18	279.28	44,188.77	2,024.66
St. deviation	596.60	3.33	4,192.33	155.78	508.37	9,026.12	880.64
Median	3,264.03	10.71	15,847.95	5,436.71	2,815.73	43,955.44	1,865.00
CV	0.18	0.29	0.26	0.27	0.18	0.20	0.43
				South-West-Oltenia			
Mean	3,376.51	7.13	10,322.38	3,027.42	1,746.62	29,591.06	1,208.00
St. deviation	883.80	1.93	2,458.92	1,148.57	376.18	10,469.04	537.44
Median	3,311.99	6.47	9,053.50	2,789.00	1,701.72	28,594.34	1,072.00
CV	0.26	0.27	0.23	0.37	0.21	0.35	0.44
				West			
Mean	3,113.40	14.54	18,603,32	5,879.11	2,848,050.00	53,972.22	2,626.08
St. deviation	697.63	4.17	6137,23	1,944.39	712.05	10,952.59	1,268.83
Median	2,937.24	14.64	18490,66	5,615.83	3,093.83	5,3037.02	2,378.50
CV	0.22	0.28	0,32	0.33	0.24	0.20	0.48
				North-West			
Mean	3,711.10	8.34	13,492.06	4,489.06	2,142.56	44,406.85	1,884.67
St. deviation	829.80	1.56	2,411.67	1,555.01	435.03	5,936.07	722.27
Median	3,419.91	7.69	13,391.99	3,847.62	2,081.02	43,824.95	1,601.50
CV	0.22	0.18	0.17	0.34	0.20	0.13	0.38

Table 2 - Continued

	Labour	UAA	Total output	Specific costs	Total farming overhead costs	Assets	Total subsidies
Central							
Mean	3,215.20	10.31	16,824.00	7,090.10	2,552.51	47,991.34	2,631.41
St. deviation	646.58	2.30	4,460.25	4,141.45	541.52	8,567.18	1,269.30
Median	3,053.75	9.63	15,977.17	5,574.52	2,429.25	43,824.95	2,262.00
CV	0.20	0.22	0.26	0.58	0.21	0.13	0.48
Bucharest-Ilfov							
Mean	2,708.86	13.22	25,980.76	4,068.93	3,900.32	166,678.20	3,060.91
St. deviation	2,070.53	9.30	23,715.10	2,290.64	3,224.79	151,469.60	2,183.96
Median	2,464.09	13.59	22,726.36	4,567.59	2,827.98	127,779.40	2,722.00
CV	0.76	0.70	0.91	0.56	0.82	0.90	0.71

Source: author's own elaboration on data available at https://agridata.ec.europa.eu/extensions/FADNPublicDatabase/FADNPublicDatabase.html.

Fig. 1 - Average results of the Data Envelopment Analysis (DEA) in all Romanian regions

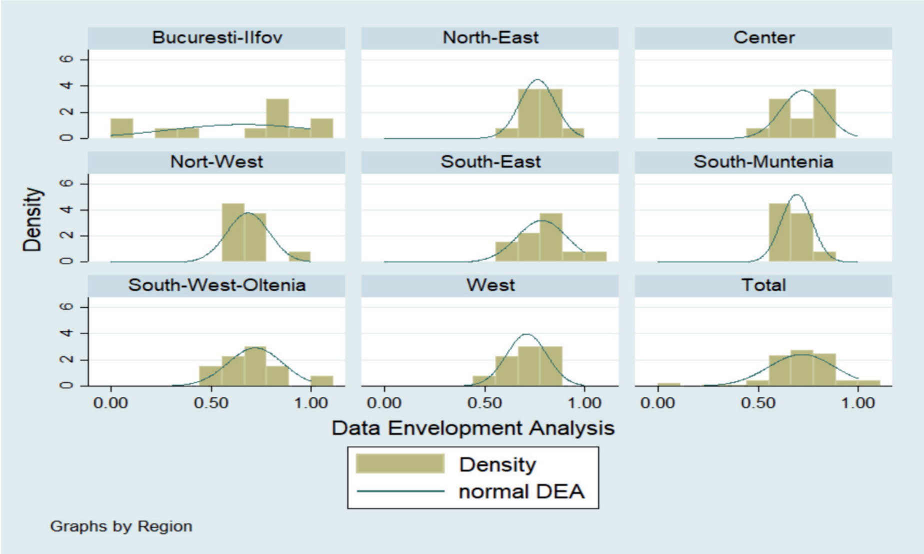


Source: author's own elaboration on data available at https://agridata.ec.europa.eu/extensions/FADNPublicDatabase/FADNPublicDatabase.html.

Comparing all Romanian regions, the highest value in terms of average land capital endowment can be found in the South-East region; in contrast, the lowest value can be found in the South-West Oltenia region, which also registered the highest level of labour capital (Table 2). Rather on its own, among all the regions of Romania was Bucharest-Ilfov, where the highest value of assets and total output were assessed, and where the lowest value of labour input was registered, which shows an average value of usable agricultural area of around 13 hectares per farm.

The assessment of the technical efficiency estimated through the Data Envelopment Analysis in an input-oriented model has revealed an average value in all Romanian regions close to 0.71 that is below the optimal threshold equal to 1 (Figure 1). The highest value of technical efficiency has been found in farms located in the South-East region whereas, in contrast, the lowest value of technical efficiency has been estimated in the Bucharest-Ilfov region, which is characterised by an adequate level of usable agricultural area and the highest level of produced output from farms. The Romanian regions of the North-West and North-East, characterised by having the highest concentration of farms, revealed the highest level of technical efficiency. In South-Muntenia where, according to the most recent Census of Agriculture carried out in 2010 by the National Romanian Institute of Statistics, there is a concentration of more than 800,000 farms out of the national total of 3.8 million agricultural holdings, the level of technical efficiency is below the national average, with many farms that are not technically efficient.

Fig. 2 - Density of the Data Envelopment Analysis (DEA) in all Romanian regions



Source: author's own elaboration on data available at https://agridata.ec.europa.eu/extensions/FADNPublicDatabase/FADNPublicDatabase.html.

Comparing the results of the technical efficiency estimated by the Data Envelopment Analysis (DEA), the distribution has been homogenous in all farms in the sample, as described in Figure 2, with some significant differences among all 8 Romanian regions, particularly the region of Bucharest-Ilfov. The research findings have corroborated that among all the farms included in the FADN dataset, few showed a value of technical efficiency close to the optimal value equal to 1, whilst the vast majority of farms in all Romanian regions have been technically inefficient, due to a non-efficient use of inputs in the productive process.

Romanian areas where the agriculture is the most important economic sector such as North-East and South-East the level of technical efficiency have been higher than areas close to urban areas such as Bucharest. The reasons of this low level of technical efficiency are due to small farms, aging of farmers and to a modest investment in improving new technologies in farms. Anyway, the land capital fragmentation is the most bottleneck influencing the management and investment choices in farms; hence, the financial subsidies of the CAP are addressed in improving generation turnover and investments in traditional crops in Romanian farms. For policy makers it is important to support farmers both the financial subsidies and decoupled payments allocated by both pillars of the CAP. The improvement of land capital endowment and investments in training are fundamental both for farmers in order to get better their technical efficiency and also for policy makers to define the main political priorities for rural areas. The estimation of the technical efficiency by a non-parametric approach has some constraints correlated to the short period of investigation; furthermore, the DEA is not able to analyse the source of inefficiency in each inputs and output which are fundamental for the policy maker in defining some specific policy measures adequate to the farmers need analysing which inputs or output are less or more technical inefficient.

In order to assess if the selected environmental variables (Z), namely different combinations of financial subsidies allocated through the first and second pillars of the Common Agricultural Policy, have had an impact on technical efficiency, a separability test as proposed by Daraio *et al.* in 2015 has been applied with a level of α of 0.05 (Kourtesi *et al.*, 2012; Wang & Schmidt, 2002). The environmental variables (Z) selected in this research were decoupled payments and direct payments allocated in the first pillar of the CAP, and financial subsidies allocated through the Rural Development Programme under the second pillar. These have generated four different combinations for the estimation of the two-stage DEA:

1. All subsidies have been estimated as environmental variables;
2. Decoupled payments and financial subsidies allocated through the second pillar of the CAP have been entered as environmental variables in the two-stages DEA;

Table 3 - Descriptive statistics comparing the DEA and the two-stage DEA using different simulations in terms of combinations of financial subsidies allocated through the CAP in the framework of the first and second pillars

	DEA	DEA 2-stages all subsidies	DEA 2-stages decoupled payments and RDP subsidies	DEA 2-stages direct payments and decoupled payments	DEA 2-stages RDP subsidies
Mean	0.71	0.66	0.66	0.66	0.67
St. deviation	0.16	0.14	0.13	0.14	0.13
CV	0.22	0.20	0.19	0.21	0.19
Range	1	0.90	0.91	0.90	0.91
Min.	0	0	0	0.20	0
Max.	1	0.90	0.91	0.90	0.91

Source: author's own elaboration on data available at https://agridata.ec.europa.eu/extensions/FADNPublicDatabase/FADNPublicDatabase.html.

3. Only the aid allocated through the first pillar of the CAP as direct payments and decoupled payments have been considered as environmental variables;
4. Only the subsidies allocated through the second pillar of the CAP in the form of RDP payments have been included in the two-stage DEA model.

The separability test has revealed that the selected environmental variables, comprising the various subsidies allocated under the first and second pillars of the Common Agricultural Policy including both direct payments and RDP subsidies, have had some effects on the function of technical efficiency, as well as on the technical efficiency score of farms. In contrast, the combination of decoupled and direct payments allocated under the first pillar of CAP has been assessed to have not acted on technical efficiency as an environmental variable in the two-stage DEA. The Levene test on the average values accepts the null hypothesis according to which the variance in all different simulations has been the same. The effect of the introduction of the environmental variables in the two-stage DEA has reduced the average value of the technical efficiency, which has shifted from 0.71 to 0.66. As such, it is possible to say that these subsidies have an impact on the technical efficiency in farms (Table 3).

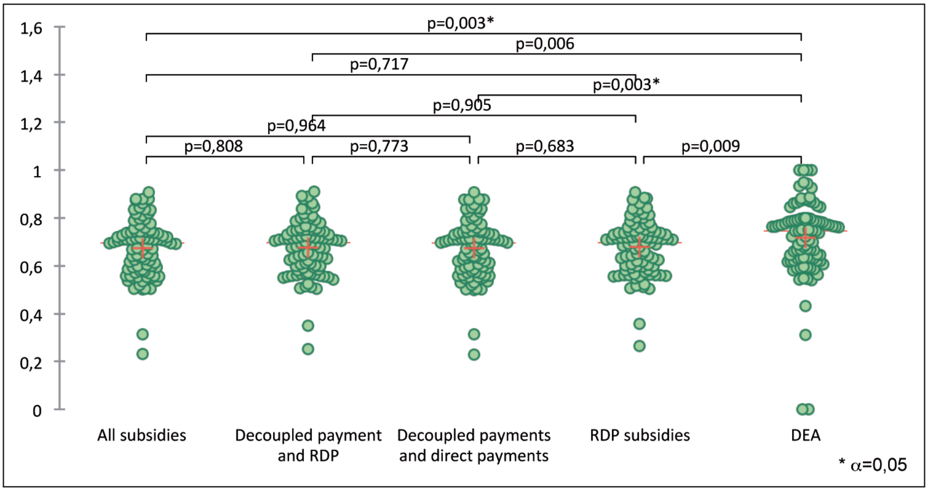
A further stage of the investigation in respect to the impact of environmental variables on the technical efficiency estimated by the Data Envelopment Analysis has used the significant difference combining the results of the DEA to the results of the two-stage DEA. The purpose of this test was to corroborate the role of the financial subsidies as environmental variables in influencing the technical efficiency.

Table 4 - Main significant differences in the estimation of the DEA and the two-stage DEA in the FADN sample

	DEA two stages in all subsidies allocated by the I and II pillar CAP	**DEA two stages in decoupled payments and RDP financial support**	**DEA two stages in decoupled payments and direct payments I pillar CAP**	**DEA two stages in RDP payments**	**DEA**
DEA two stages in all subsidies allocated by the I and II pillar CAP	No	No	No	No	YES
DEA two stages in decoupled payments and RDP financial support	No	No	No	No	No
DEA two stages in decoupled payments and direct payments I pillar CAP	No	No	No	No	YES
DEA two stages in RDP payments	No	No	No	No	No
DEA	YES	No	YES	No	No

Source: author's own elaboration on data available at https://agridata.ec.europa.eu/extensions/FADNPublicDatabase/FADNPublicDatabase.html.

Fig. 3 - Level of significance comparing DEA to the different two-stage DEA in all Romanian regions under the four simulations



Source: author's own elaboration on data available at https://agridata.ec.europa.eu/extensions/FADNPublicDatabase/FADNPublicDatabase.html.

Table 4 shows the significant differences comparing the results assessed by the DEA and the different combinations of the two-stage DEA in all Romanian farms included in the FADN dataset. The findings have revealed that there is some level of divergence comparing the two-stage DEA, estimating that all the financial subsidies allocated through the CAP and the financial subsidies allocated through the first pillar only, or rather decoupled and direct payments, have had some effect, with a level of significance of < 0.01 (Figure 3).

4. Conclusions

The rural and agricultural fabric in Romania is characterised by small farms scattered, particularly in rural areas, across several plots of land, for which it is very difficult to improve productivity and technical efficiency through investment in labour-saving machines and other equipment. In fact, according to the Eurostat, more than 95% of Romanian farms have less than 5 hectares of land capital. As such, the role of financial subsidies, particularly through the second pillar of the CAP, should be to increase investment in technology and promote greater diversification in farming activity, with the aim of enhancing farmers' income and, consequently, reducing the level of permanent rural emigration. The poor endowment in land capital is one of the most important constraints in agriculture, while at the same time, the low level of investment is the main factor responsible for a modest level of asset ownership and a high demand for labour, predominantly from within the family unit, for which it is possible to define a specific Romanian model of labour-intensive family farming.

This research has underlined that, in order to increase the level of asset ownership in farms that could, at the same time, reduce the high demand for labour – two factors that are important for increasing the technical efficiency in farming and, thus, the socio-economic survival of farms – the financial subsidies allocated through the European Union in the framework of the Common Agricultural Policy are fundamental. In fact, the two-stage DEA has confirmed, through the separability test, the role and impact of these environmental variables in increasing the technical efficiency in farms.

The analysis has also underlined the value of this quantitative approach in assessing the impact of environmental variables on technical efficiency. In particular, using the test of separability it has been possible to identify a discernible impact of environmental subsidies on the technical efficiency estimated in the first stage by the Data Envelopment Analysis. In regards to the implications of the two-stage DEA for policy in assessing the importance of financial subsidies on farms, moreover, this study shows that it has been possible to estimate which different combinations of subsidies can act on the technical efficiency in Romanian farms. Findings in this analysis have underlined as Romanian farms need of CAP subsidies in order to improve their technical efficiency and their effect is positive and clear if farms receive subsidies both by the first and also by the second pillar of the CAP. An unique type of subsidies is not adequate to improve the technical efficiency in Romanian farms. For the policy makers is important to tailor measures of intervention adequate to increase technical efficiency in farms, also able to encourage some structural changes in Romanian farms such as generational turnover, investments in labour saving techniques and increasing of land capital. For the future it is important to deal with the role of generational turnover in farm as a tool improving the technical efficiency in Romanian farms investigating also the casues of inefficiency in each input and output.

Drawing some conclusions, the findings have underlined the importance of financial subsidies allocated by the first and second pillars of the CAP to farming in Romania. In particular, subsidies paid under the first pillar of the CAP have been shown to have had an impact on the level of technical efficiency, while, due to the modest amounts involved, the research outcomes have not revealed any discernible impact of financial aid disbursed through the second pillar.

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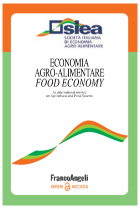
Economia agro-alimentare /
Food Economy

An International Journal on Agricultural and Food Systems

Vol. 23, Iss. 3, Art. 6, pp. 1-32 - ISSN 1126-1668 - ISSNe 1972-4802
DOI: 10.3280/ecag3-oa12755



Generating cropping schemes from FADN data at the farm and territorial scale

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Abstract

The paper presents an innovative approach to cropping scheme classification based on FADN data with two main goals. First, the identification at the regional level (NUTS2) of land use patterns common to similar farms defined 'group cropping scheme'. Second, the farm-level construction of farm cropping schemes, which expand the observed crop mix and identify suitable variation ranges considering the farm production context. The schemes are based on the observed behaviour of homogeneous farms and capture their common structural characteristics regarding land use.

The schemes can be used at the territorial scale to analyse land-use trends and patterns over time. At the farm level, the method is designed to analyse short-term adaptations and is suitable to be used, together with other data, in mathematical programming models to run policy analysis exercises. At this latter scale, crop substitution within a scheme allows the set of eligible crops to be expanded while remaining linked to the observed behaviour on a spatial basis.

The paper applies the methodology to identify and quantify the cropping schemes using FADN data on Italian farms specialising in annual field crops. An algorithm implemented in GAMS automates the process. Results confirm the validity of the method and open a field of research for future applications.

Article info

Type:
Article
Submitted:
15/05/2021
Accepted:
10/09/2021
Available online:
12/01/2022

JEL codes:
Q1, C6

Keywords:
FADN
Cropping schemes
Land use
Modelling

Managing Editor:
Lucia Briamonte,
Luca Cesaro,
Alfonso Scardera

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Introduction

Land use is an interesting topic for researchers and institutions, and farmers who must make their choices. Many studies deal with the productivity and economic potential of different cropping systems. However, it is not simple to characterise the crop mix adopted in a given region or country.

This paper is a technical paper proposing a new method to identify and quantify cropping schemes based on FADN data, and the aims are:

- the identification at the territorial scale of land use patterns common to similar farms defined "group cropping scheme";
- the construction at farm level of homonymous cropping schemes, designed to support mathematical programming models, which expand the observed crop mix and identify suitable variation ranges considering the farm production context.

The schemes are based on the observed behaviour in homogeneous groups of farms and capture their common structural characteristics regarding land use. At the farm level, central is the concept of crop substitution within a scheme, which allows the set of eligible crops to be expanded while remaining linked to the observed behaviour on a spatial basis. To clarify, consider a group of farms with similar characteristics in: time, space and agricultural activity; assume that all produce cereals, but only a few in the group a certain cereal; these farms can represent innovators. The methodology allows similar farms to adopt this crop, but with limits on the maximum area, which considers the total cultivated area at the farm and its potential expansion estimated at a territorial scale. In this way, innovation can be spread out. Land use variations can apply only to annual crops; for this reason, farm cropping schemes are designed to analyse short-term adaptations, but they respond to any drivers of change and are therefore suitable to be used in policy analysis studies integrated with other data.

The paper focuses on the description and testing of the method proposed to identify and quantify the cropping schemes at both territorial and farm scales; its application to specific studies shall be done in future studies.

The cropping schemes cannot be identified with crop rotation systems which are the practice of growing different crops on a parcel of land from one year to the next and represent an agronomic tool to maintain soil fertility, affecting the economic performance (Li *et al.*, 2015) and influencing the rural landscape.

Important differences exist between the two approaches:

a) rotations require data for a reasonable number of successive years, while only one year is sufficient for cropping schemes;
b) rotations are farm-specific; cropping schemes are structures that fit all farms in a similar group;

c) rotations include only the observed crops in the farm over the period; cropping schemes, instead, enlarge the set of observed crops at the farm by the crops cultivated in farms with the same characteristics, as detailed below;
d) rotations are rigid in terms of crop areas, the percentage of the crops in each year of the rotation are fixed values; cropping schemes, instead, offer a range of surface for each crop.

Previous analysis at territorial scale exist (Kollas *et al.*, 2015); among them, an interesting approach is proposed by Vitali *et al.* (2012). A central aspect is the availability of adequate data to investigate land use. The FADN database represents an important source of real field data at the national level. An alternative data source could be the census data that counts more farms than FADN and reports information to define farm structures and rotational schemes. However, census data is collected every ten years, whereas FADN data records a high variability among years. For this reason, a time step of 10 years could be too wide to describe the farm dynamics. Therefore, while on the one hand, the census data could be a better source because it provides a complete picture, on the other hand, census data do not have enough repetitions to describe so variable situations among years (Albertazzi, 2014).

The application of the proposed method on FADN data through an ad hoc procedure implemented in GAMS is still FADN, and it is limited to Italian farms specialising in annual open field crops. These farms present a greater variability in land use; for them, there is a need to acquire reliable production patterns and represent a suitable context to test this method.

1. Background

Land use is affected by market rules, administrative policies, farmer knowledge, and climate and slope. Diversification of crop rotations is considered an option to increase the resilience of European crop production under climate change (Kollas *et al.*, 2015). In fact, rotations are often included as an indicator of a degree of compliance with the principles of sustainable agriculture (Bazzani *et al.*, 2021; Kraatz *et al.*, 2019; Di Bene *et al.*, 2016). They are also indicated as sustainable practices in the Common Agricultural Policy. One of the most relevant changes towards sustainability in farm management could be upgrading crop diversification, for instance, requiring specific crop rotation (Cortignani and Dono, 2020). All of these factors define crops available for the farm manager's choice and related practice.

Many studies describe experimental crop rotations to evaluate crop yield, nutrient balance and organic matter level in the soil. Some of these studies are based on the adoption of mathematical models designed with the intent to support farmers in making optimal crop and crop management choices in a complex environment (Pahmeyer *et al.*, 2021; Vigneswaran and Selvaganesh, 2020). Peltonen-Sainio *et al.* (2020) developed an interactive, multi-step crop rotation tool, which acknowledges farmer's preferences in land allocation for different crops depending on the farm and field parcel characteristics. Others (Purola and Lehtonen, 2020; Purola *et al.*, 2018; Liu *et al.*, 2016) applied dynamic optimisation farm models with multiple input-use responses on crop yields. Explicit field parcel-specific crop-rotation constraints are accounted for in solving the farmers' decision problem of soil-renovation investments.

Some studies have demonstrated that farmers' profit also depends on crop rotation scheduling: Li *et al.* (2015) have proposed an operational model that considers crop rotation scheduling to identify the optimal rotation that maximises prices and minimises the profit differences between smallholder farmers. Mohring *et al.* (2010) have applied econometric estimates of production and consumption functions and in this case, rotations are considered a sort of ecological constraint; Pahmeyer *et al.* (2021) have developed a decision support system about alternative cropping and fertilizer management choices where have ranked the desirability of crop rotations, highlighting economic consequences of management choices.

The studies highlight the need for access to the most complete and consistent data with the research aims. The farm accountancy data network (FADN) mainly provides extensive information on the economic performance of farms (European Commission - EU FADN, 2018; Finger and El Benni, 2014) and can be used to highlight the relationships between the adoption of European policies and producer's investment (Klepacka *et al.*, 2019; Purola *et al.*, 2018; Bezat-Jarzębowska *et al.*, 2014; Arfini and Donati, 2013). FADN data are used as a source of information in estimation methodologies to assess the effects of agricultural policies (Cagliero *et al.*, 2018). The use of data from the FADN is widespread, and there is a large number of papers based on this information and research groups dealing with it (PACIOLI workshop[1], several years). In recent years, an increasing number of studies have used FADN data both as a statistical source and as a fundamental way of collecting a range of information needed to analyse the business effects of complex processes in several farming contexts (Forleo *et al.*, 2021; Cristiano *et al.*, 2020). FADN data are also used to draw on unique multicriteria assessments to compare economic and environmental objectives and assess their compatibility (Špička *et al.*, 2020).

1. "Every year Wageningen Economic Research (formerly known as LEI) organises the Pacioli workshop on the collection and use of farm level data for policy analysis, research and extension. An example of such a farm level data system is the European Farm Accountancy Network (FADN)", www.pacioli.org.Fad.

Several works have been indicating rotations as elements to be considered in the analysis and have used FADN data, among them: simulation models for the study of relationships between the policy and economic rent (Offermann and Margarian, 2014; Dell'Aquila and Cimino, 2012; Poppe *et al.*, 1999); management of agronomic practices related to climate change, in particular, CO_2 abatement (Bazzani *et al.*, 2021); the definition of a farm sustainability index as a support tool to policies (Sulewski and Kłoczko-Gajewska, 2018); compliance with agri-environmental regulations (Jensen and Ørum, 2014); to check the suitability of the most popular biodiversity indices for measuring the level of diversification of cropping structure for assessing the fulfilment of CAP greening criteria (Was and Kobus, 2014).

2. Data and methods

Data

The Italian section of FADN, RICA (Rete di Informazione Contabile Agricola), is the data source. FADN collects accountancy information from a representative sample of EU farms. In Italy, data collection and maintenance are carried out by CREA-MIPAAF (National Council for Agriculture Research and Agricultural Economics, of the Ministry of Agricultural, Food and Forest Policies). The collected information includes structural aspects (e.g., cropped surface, workforce) and economical information (e.g., producing value, goods and services purchased and sold, subsidies).

Since 2003, the principle that the farm sample should represent a country farm universe has been introduced. Farm selection is in agreement with the results of the investigation of economic performances of farm holdings (REA) managed by the Italian National Institute for Statistics (Istat). This approach allowed to give each farm a weight estimating its representation on a national basis, which is obtained from three data; location (NUTS2)[2], economic size (since 2009 expressed in Euro) and type of farming.

The 2012-2016 databases have been used, considering the Emilia-Romagna region only; since in 2016 the composition of the database has been drastically changed, only 6 farms are present over all the period. Cropping schemes have been estimated for all the five years. Results show variation in land use which are captured by the FADN database. In the context of this paper, which is a technical one, the focus is not on the application of cropping schemes to any specific study but rather on the methodology itself, thus result only refers to 2016, the most recent year.

2. In Italy corresponds to administrative Regions.

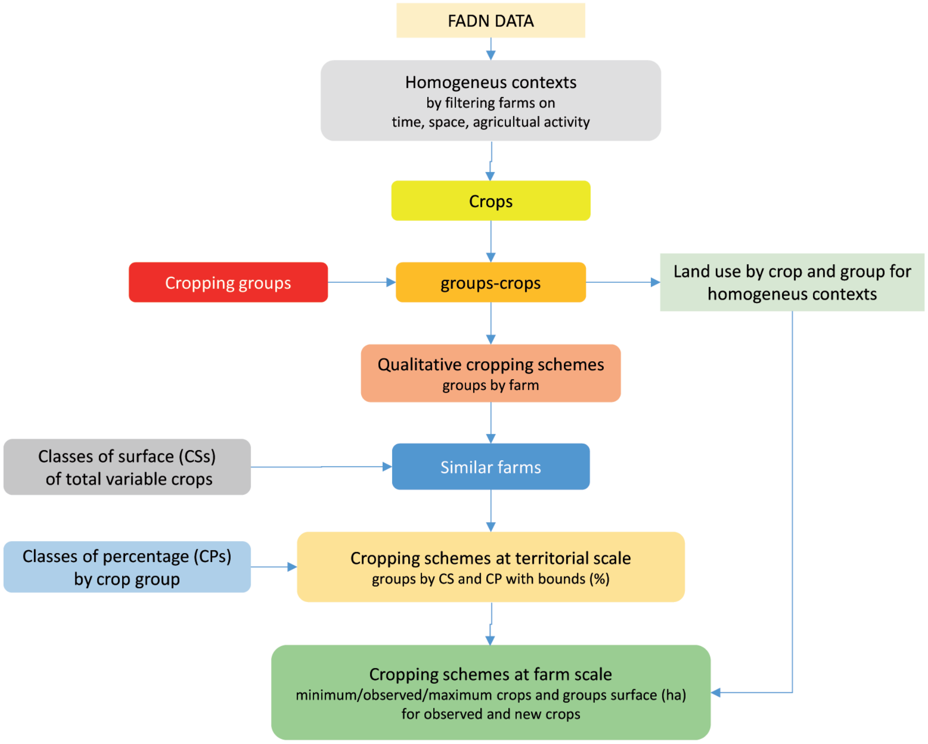
Methods

The method is graphically described in Figure 1. In the first phase, starting from the FADN data, a filtering procedure identifies homogenous context considering three dimensions: time, space and agricultural activity. The linking of predefined crops groups with the observed farms crops leads to the creation of qualitative cropping schemes at group level and to describe land use by the context in terms of covered surface. In the second phase, the introduction of surface classes "CSa", based on the total variable area at the farm, identifies similar farms. The additional component of the group percentage class "CP" allows estimating group cropping schemes at a territorial scale. Finally, cropping schemes are defined at the farm level and are expressed in hectares providing the variation range both for groups and crops, expanding the crop mix to all the crops observed in similar farms.

The procedure is implemented in GAMS and requires only few seconds to run.

It is explained in detail in the next section.

Figure 1 - Flow diagram of the method



Cropping schemes at territorial scale

The first phase involves a filtering procedure of the FADN database to identify a set of farms with the same technical orientation and active in a homogeneous context from a climatic and territorial point of view in a certain year. This approach makes it possible to reduce the universe to subsets of similar farms, on which subsequent processing is easy, and representative situations can be derived.

Three main dimensions have been identified to identify the context: time, space and agricultural activity, articulated into one or more criteria as outlined below.

1. time: one or multiple years, referred to the years of the farms in the FADN sample
2. space:
   - 2.1. macro area
   - 2.2. administrative region
   - 2.3. climatic zone
   - 2.4. altimetric zone
   - 2.5. slope
3. agricultural activity:
   - 3.1. conventional or organic
   - 3.2. type of farming[3], identifying the main products such as annual crops, horticultural, perennial cultivation
   - 3.3. legal form
   - 3.4. type of occupation, based on employment and external services
   - 3.5. disadvantaged area
   - 3.6. livestock, describing the existing animals if any

Most of the previous data are collected from the "FARM" table in the FADN database. Other criteria may be introduced if requested, and FADN or other available source provides the necessary data.

The method in the next phases is applied separately by context.

The table "crops" in the FADN database contains the land use area data of the farms selected, identifying the crops and their surface; this is the main data source for the procedure.

The method requires the prior association of crops in crop groups; the latter are defined based on agronomic, productive and commercial criteria.

The cropping schemes are designed to analyse short-term adaptations; for this, the distinction of groups and crops into fix and variable is requested. Most of the annual crops which can change every year are considered variable. Fixed groups include perennial crops or crops with multiple year

3. OTE in the Italian FADN database.

cycles, such as orchards, vineyards, rice fields, but also some annual crops such as flower plants, nursery and ornamental plants are considered fixed due to the infrastructures required and the complexity of the production process, which block short term adaptation.

The identification of the groups and the relation with crops is done by hand. The crop-group relation must capture the local agricultural productive context and should be implemented by experts knowing the specificities of the analysed systems. Cluster analysis is not recommended, it has been tested but the result have not been satisfactory. There is not a unique way to identify and create groups. The central concept that must be preserved is crops substitution within a group; in fact a group should include crops that can be interchangeable at farm level, due to not to different productive requirements in term of farmers knowledge and equipment in a homogeneous context.

For example, in a plain area of Emilia-Romagna, with irrigation available, distinct groups include cereals, vegetables, legumes, oilseeds, industrial crops, fodder crops, meadowland, textiles, seeds, rice, tobacco, aromatic and officinal, flower plants, nursery and ornamental plants, pasture and meadows, orchards, uncultivated area.

In the same region in 2016, the cereals group based on FADN data comprises the following crops: durum wheat, tender wheat, hybrid corn, native corn, barley, sorghum, triticale, cereals other from grain. In other years and/or regions the crops included in the cereals group may be different.

Fixed and variables groups may be both included in a cropping scheme, but only the latter are relevant to analyse land-use change in the short term (Table 1).

Different groupings are possible; for instance, the group of industrial crops that may comprehend potato, tomato, and sugar beet could be split by creating separate groups for the three previous crops. The split would prevent a farm growing tomato from switching to potato or sugar beet, which could happen if they are all included in the same “industrial crops” group. The choice to keep crops in a common group or separate them in distinct ones should always be based on the local conditions and existing agriculture practices.

If new crops are added to the FADN database over time, they must also be added to the previous table. Even if the crops-groups relation is fixed, the crops included in a group may vary by the context and over time in accordance with the FADN data.

The procedure assigns to each observed crop the related group and creates the qualitative cropping scheme, which is the set of the groups at the farm level. For example, if three farms cultivate processing tomato (classified as an industrial crop) associated with durum wheat, tender wheat, or hybrid corn, only one cropping scheme, including cereals and industrial crops, will be considered.

Table 1 - Cropping groups classified by permanence

Groups	Fixed	Variable
Plantations	X	
Aromatic and officinal	X	
Flower plants	X	
Nursery and ornamental plants	X	
Pasture and meadows	X	
Orchards	X	
Rice	X	
Cereals		X
Legumes		X
Oilseeds		X
Industrial crops		X
Tobacco		X
Textiles		X
Seeds		X
Vegetables		X
Meadowland		X
Fodder crops		X
Uncultivated area		X

The qualitative cropping scheme does not provide any quantitative information; it simply identifies the crops groups of the farm based on the observed crops.

In this stage, crop surfaces, observed in the table 'crop', are used to describe land use by the context in terms of covered area. The information expressed in percentage allows to capture the relative importance of crops and groups. This information will be used in the final stage of the procedure at the farm level to enlarge the crop mix.

In the next step, the procedure uses the data of crop areas at the farm to create a quantitative cropping scheme at the group level. Only the variable crops are considered since they can change the cultivated surface in the short term, the reference period for the methodology.

Two distinct types of classes are requested for this purpose:

- the first one considers the total area of variable crops; four surface classes have been defined, indicated with CS1-CS4, with ranges expressed in

hectares, respectively: <5, 5-15, 15-40, >40; the procedure assigns each farm to one of the previous classes summing the surface of the observed variable crops, on the basis of the previously defined membership relation;
- the second one considers the incidence of a group on the total variable farm area; four percentage classes (CP1-CP4) have been defined with intervals equal to: <10%, 10%-25%, 25%-50%, >50%. The area of the group, equal to the sum of the areas of the included crops, divided by the total variable farm areas, allows the group's assignment to one of the previous classes.

The CSs replace the group surface, an exact value equal to the sum of the observed crops in a farm included in the group, with a range. Farms of a context assigned to the same CS are defined as 'similar'.

The joint consideration of the two classes allows to build a table in which the rows report the qualitative schemes, the groups present on the farms, each identified by the identification number in position one and the farm surface class (CS) in position two; the columns (CPs) provide quantitative information on the incidence of the groups on the total of variable crops of each farm.

Table 2 shows an example with three farms, having respectively 4, 2 and 3 groups; these are, therefore, three different schemes. The cereals group is always present in class CP4, which means that covers more than 50% of the total variable crop surface of the tree farms, which in the first case is in the range 15-40 ha (CS3), in the second case is in the range >40 ha (CS4), in the third case is in the range 5-15 ha (CS2). The fodder crops group appears in two farms ID[4] 2602016015909000001 and ID 2602014015001000001 with different total variable crop surface, respectively CS3 and CS2, once in CP1 (<10%), and once in CP3 (25%-50%).

As illustrated in the next section, the complete analysis of the schemes shows that they are recurrent, albeit in different ways. As expected, few schemes collect the vast majority of farms, while a larger number of schemes are observed only a few times.

The analysis so far allows an aggregated and synthetic representation of land use in a homogenous area by identifying prevailing/ordinary and extraordinary behaviours. The group schemes do not consider crops but identify crop groups and the related percentage on the total variable area.

The method, in the next step, set lower and upper extremes to the groups by scheme, keeping separate the CSs, which means by similar farms.
- If a scheme in a certain CS is present only once, the minimum and maximum values coincide with those of the observed CP for all the included groups.

4. ID is the farm identification code.

Table 2 - Cropping schemes by total variable surface and group percentage classes

	CP1	CP2	CP3	CP4
2602016015909000001.CS3.fodder crops	X			
2602016015909000001.CS3.cereals				X
2602016015909000001.CS3.legumes		X		
2602016015909000001.CS3.industrial crops			X	
2602016015467000001.CS4.cereals				X
2602016015467000001.CS4.legumes		X		
2602014015001000001.CS2.uncultivated area			X	
2602014015001000001.CS2.fodder crops			X	
2602014015001000001.CS2.cereals				X

- When a scheme appears in more than one farm with the same CS, two situations are possible:
  – all farms have the same CP for all groups; this is like the previous case;
  – the CPs in one or more groups are different among the farms; in this case the extreme limits of the CPs concerned are taken.

To clarify the latter situation consider the following example. Scheme 28 comprehends two groups, cereals and industrial crops and is observed in two farms in CS3. Groups surface by farm are reported in Table 3.

Table 3 - Surface by group for farms with cropping scheme 28

	Tot.	Cereals		Industrial crops	
Farm ID.Class of surface.Scheme	**ha**	**ha**	**%**	**ha**	**%**
2602008010991000001.CS3.sch28	14.98	12.57	83.91	2.41	16.09
2602016015902000001.CS3.sch28	14.97	9.72	64.93	5.25	35.07

The first group, cereals, covers 83.91% and 64.93% of the total farm variable area, and in both cases, is assigned to CP4. Industrial crops cover 16.09% in the first farm and 35.07% in the second farm, corresponding to CP2 and CP3, respectively.

When this information is aggregated over the farms, CP4 is the only class for the cereals group; instead, the industrial crops group appears in two classes CP2 and CP3, as shown in Table 4, where farm IDs do not appear anymore.

Table 4 - Group percentage classes in cropping scheme 28

Class of surface.Scheme.Group	CP2	CP3	CP4
CS3.sch28.cereals			X
CS3.sch28. industrial crops	X	X	

The extreme of the observed CPs gives the range of variation of each group. The range of CP4 gives the bounds for the cereals group (50%-100%). For industrial crops, since two classes CP2 and CP3 exist, the lower bound of CP2 (10%), which is the minimum value, represents the lower limit, while the upper bound of CP3 (50%), which is the maximum value, represents the upper limit, as shown in Table 5.

Table 5 - Group ranges in scheme 28 for surface class CS3

Class of surface.Scheme.Group	CP2.mi	CP3.ma	CP4.mi	CP4.ma
CS3.sch28.cereals			50	100
CS3.sch28.industrial crops	10	50		

The upper and lower limits thus constructed may require corrections to meet the following requirements:

- minimum and maximum bounds within a group must be compatible with the scheme;
- for each group the bounds must be compatible with the values observed in the other groups of the scheme.

If a scheme comprises only one group, the minimum and maximum are set equal to 100 so that the whole arable land is used, to respond to the former requirement.

If more groups exist, which is the common situation, for each group the following rule must hold: the value of the group maximum plus the sum of the minimum of all the other groups belonging to the scheme must be equal or lower than 100.

When this rule does not hold some values must change. The choice is to keep unchanged the minima (mi), the lower bound, and reduce the upper bounds (ma) of the group. This restricts the range of variation for the group. The correction is done applying the following formula:

$$\widetilde{ma}_i = 100 - \sum_j mi_j \quad \vee \ i \neq j \qquad \textit{Eq. 1}$$

Where ‘i’ and ‘j’ identify different groups within the same scheme.

In the previous scheme 28 in Tab. 4 cereals have a maximum of 100% which is not compatible with the minimum of 10% for industrial crops, in fact the sum is 110%. Applying *Eq.* 1 the value of 100 is lowered to 90.

Another example refers to scheme 7. A large farm in CS4 comprehends three groups: cereals, legumes, industrial crops, respectively in CP4, CP1 CP2, as showed in Table 6 where the class percentages are reported.

Table 6 - Cropping scheme 7 initial bounds in per cent of total variable area

CS.scheme.group	**mi %**	**ma %**
CS4.sch7.cereals	50	100
CS4.sch7.legumes		10
CS4.sch7.industrial crops	10	25

Consider the cereals group, the maximum equal 100, plus the minimum of the other groups (0 and 10) sum 110. The maximum is reduced to 90, subtracting from 100 the sum of the minimum of the other groups (0+10). The sum of the three percentage (90+0+10) is now 100, which is correct (Table 7).

Table 7 - Cropping scheme 7 final bounds in per cent of total variable area

CS.scheme.group	$\widetilde{mi}$ **%**	$\widetilde{ma}$ **%**
CS4.sch7.cereals	50	90
CS4.sch7.legumes		10
CS4.sch7.industrial crops	10	25

In cropping scheme 3 two groups require correction, as shown in Table 8, cereals and fodder crops have two high values (50+10+50=110) and (100+10+25=135), respectively.

Table 8 - Cropping scheme 3 initial bounds in per cent of total variable area

CS.scheme.group	**mi %**	**ma %**
CS4.sch3.uncoltivated area	10	25
CS4.sch3.cereals	25	50
CS4.sch3.fodder crops	50	100

The maximum value (ma) have been reduced to $\widetilde{ma}$ in Table 9, with the formula in Eq. 1. Cereals 100 – (10 + 50) = 40 and fodder crops 100 – (10 + 25) = 65.

Table 9 - Cropping scheme 3 final bounds in percentage of total variable area

CS.scheme.group	$\widetilde{mi}$ **%**	$\widetilde{ma}$ **%**
CS4.sch3.uncoltivated area	10	25
CS4.sch3.cereals	25	40
CS4.sch3.fodder crops	50	65

The method so far leads to the identification of 'group cropping schemes' that quantify the minimum and the maximum percentages of the total variable area by group and can be applied to similar farms, considering the context and the farm CS.

The following aspects of the schemes at territorial scale should be highlighted:

- they apply to similar farms;
- groups and not crops are considered;
- values are percentages and not areas.

Cropping schemes at farm scale

The next step applies to the cropping schemes to the original farms, and moves from percentages to surfaces.

The farm's total variable surface, related with the CS, multiplied by the group percentage, quantifies the range of variation in hectares for the groups.

Crops can now be introduced into the schemes.

For each farm, the crops observed (obs) in the table crop of the FADN are first included. A test verifies that the minima and maxima calculated for the groups to which the crop belong are compatible with the observed crop values; in fact, the method preserves the observed farm production mix. The minimum area is quantified first, multiplying the observed surface by the minimum percentage of the group. The maximum area for each observed crop is set equal to the surface of the group to which it belongs minus the sum of other crops included in the group.

The introduction of new crops now expands the crop mix. This process broadly reflects the production behaviour adopted by similar farms based on the criteria set out above, which ensure similarity of climatic and territorial conditions and farm, structural and management conditions. Therefore, the cultivation of the new crops should be compatible with the farmer's skills and aptitudes and the existing machinery and equipment without the need for new investment. This approach makes it possible to identify common situations among farms and enlarge the farm cropping mix based on the behaviour of similar ones.

For example, if durum wheat and barley, which are cereals, are present in a homogeneous context, these crops can be introduced on farms that do not grow if they are similar to those where these crops are observed and already grow cereals. In the same way, new vegetable crops, such as industrial crops, can only be introduced on farms where those groups are already grown and if similar farms grow them.

The range of variation for the new crops has a minimum of zero, the only value which does not force cultivation and is therefore compatible with the observed situation in which these crops are not present. The crop upper bound is, instead, always defined and is positive; it is quantified considering the territorial coverage of the crop in similar farms and it is expressed as percentage on the group to which the crop belongs. This percentage multiplied by the area of the group on the farm quantifies the crop upper bound as showed in the next section.

Crops with a maximum surface lower than 0.1 hectares are eliminated, as this value is set as the lower limit for the cultivated area.

The cropping schemes refer now to farms and quantify surface values expressed in hectares.

3. Proof of concept

The method was automated through a code written in GAMS (Bussieck and Meeraus, 2004) and applied experimentally to several Italian production sites. One is illustrated here in detail to allow full understanding.

The Emilia-Romagna case study

The first part of the procedure aims to identify the "context" which is a homogeneous sample from the Italian FADN database. The following criteria have been defined to the purpose:

1. time: 2016
2. space:
   2.1. macro area: Nord Italy

2.2. administrative Region, Emilia-Romagna
2.3. climatic zone: castanetum[5]
2.4. altimetric zone: plain
2.5. slope: < 5%
3. agricultural activity:
3.1. conventional
3.2. pool type of farming: 1 field cropping
3.3. type of farming: 1510, 1520, 1530, 1610, 1620, 1630, 1660
3.4. legal form: simple company, sole proprietorship
3.5. type of occupation: direct
3.6. disadvantaged area: no
3.7. livestock: not present.

A subsample with 119 farms was extracted, with a total area of 8284.53 hectares, of which 7708.21 are allocated on variable crops. Almost all of them are medium-large farms, the average area of variable crops being about 65 hectares.

The distribution of farms between variable surface size classes (CSs) shows that the two largest classes account for 79% of the sample, with only one holding in the smallest class (Table 10).

Table 10 - Farms by variable surface size class

CS1	CS2	CS3	CS4	Total
1	24	49	45	119

Based on the annual field crops observed in the sample, nine crop groups have been defined: uncultivated area, meadowland, fodder crops, cereals, legumes, oilseeds, industrial crops, seeds, vegetables.

The crops have been associated with the groups, as illustrated in Table 11.

5. Classification has been done using a national phyto-climatic mapping developed by Tomaselli *et al*. (1973) and Pedrotti (2013), defining five classes: Z1-Lauretum, Z2-Quercetum, Z3-Castanetum, Z4-Fagetum and Z5-Picetum; the choice revealed to be a good compromise in terms of resolution and complexity.

Table 11 - Crop-group associations for field cropping

Crop	Group	Crop	Group
Supported set-aside	Uncultivated area	Sweet corn	Industrial crops
Unsupported set-aside	Uncultivated area	Potato	Industrial crops
Durum wheat	Cereals	Other industrial crops	Industrial crops
Tender wheat	Cereals	Soybean	Legumes
Hybrid corn	Cereals	Broad bean	Legumes
Native corn	Cereals	Chickpea	Legumes
Barley	Cereals	Seed fodder crops	Seeds
Sorghum	Cereals	Seed vegetables	Seeds
Triticale	Cereals	Garlic	Vegetables
Cereals other from grain	Cereals	Table tomato	Vegetables
Grass meadowland	Meadowland	Watermelon	Vegetables
Legumes meadowland	Meadowland	Melon	Vegetables
Alfalfa	Fodder crops	Peas	Vegetables
Ryegrass	Fodder crops	Green beans	Vegetables
Other fodder crops	Fodder crops	Onion	Vegetables
Silo corn	Fodder crops	Endive	Vegetables
Sunflower	Oilseeds	Chard	Vegetables
Rapeseed	Oilseeds	Shallot	Vegetables
Other oilseeds	Oilseeds	Spinach	Vegetables
Industrial tomato	Industrial crops	Pumpkin	Vegetables
Sugar beet	Industrial crops	Other vegetables	Vegetables

The distribution of the groups in the 119 farms is very different: cereals are present in 33 farms, 27,73% of the total; followed by: fodder crops 18.49%, industrial crops 14.29%, legumes and vegetables 11.76%, as reported in the first two columns in Table 12.

Cereals cover over 57% of the cultivated area at variable crops, fodder crops (15.11%), industrial crops (12.97%) and legumes (8.30%) are the only groups over 5% of the total.

Table 12 - Farms and surface by groups

	Farms		Surface	
Group	**n**	**%**	**ha**	**%**
Uncultivated area	5	4.20	22.87	0.30
Meadowland	4	3.36	126.36	1.64
Fodder crops	22	18.49	1165.09	15.11
Cereals	33	27.73	4424.16	57.40
Legumes	14	11.76	640.11	8.30
Oilseeds	7	5.88	158.94	2.06
Industrial crops	17	14.29	999.52	12.97
Seeds	3	2.52	67.30	0.87
Vegetables	14	11.76	103.86	1.35
Total	**119**	**100.00**	**7708.21**	**100.00**

Cropping scheme at territorial scale

The algorithm, on the basis of the associations defined in Table 11, identified 37 different patterns in the 119 farms, defined "qualitative cropping schemes". Table 13 lists the schemes on the rows and the groups on the columns. The presence of an 'x' in the box indicates that the group is part of the scheme.

The number of groups present in the schemes ranges from 1 to 5. Schemes with three and four groups are the most frequent (30% each); only three schemes include only one group; 7 schemes have two groups; 5 schemes include 5 groups (Table 14).

The number of schemes observed vary by the number of groups, as reported in Table 15. Schemes with two and three groups are the most frequent, with 45 and 36 cases, respectively. Schemes with only one group are observed in 14 farms; the presence of 5 groups is observed only six times.

Sixty-two farms are concentrated in 4 schemes: 19 in scheme 8; 16 in schemes 2 and 7; 11 in scheme 16.

The land size class is considered to calculate the percentages of the crop groups within the schemes. For example, scheme 9 includes three groups: fodder crops, cereals, legumes, and is present in farms belonging to classes CS3 and CS4 (Table 16).

Comparing the two CSs, it can be observed that while cereals are always present with the same percentage of the total that goes from 25% to 100% of the total area under variable crops; the situation is different for fodder crops

Table 13 - Qualitative cropping schemes

Scheme	Uncultivated area	Meadowland	Fodder crops	Cereals	Legumes	Oilseeds	Industrial crops	Seeds	Vegetables
1			X	X	X		X		
2				X	X				
3	X		X	X					
4	X		X	X			X		X
5				X	X	X	X		
6			X	X	X	X			
7				X	X		X		
8			X	X					
9			X	X	X				
10			X	X			X		
11				X		X			X
12			X						
13			X	X			X		X
14			X	X					X
15				X		X	X		X
16				X					
17		X	X	X					
18			X	X	X	X			X
19			X	X	X		X		X
20	X			X	X				X
21		X	X	X			X		
22		X	X						
23				X					X
24		X	X	X	X		X		
25							X		X
26				X	X		X		X
27	X		X	X	X				
28				X			X		
29							X		
30			X	X				X	
31			X	X		X			
32	X			X					
33			X	X	X			X	
34			X	X			X	X	X
35				X	X				X
36			X	X		X	X		
37				X			X		X

Table 14 - Count of schemes by the number of groups

N. of groups in the scheme					
1	**2**	**3**	**4**	**5**	**Total**
3	7	11	11	5	37

Table 15 - Count of farms by group of crops

N. of groups in the scheme					
1	**2**	**3**	**4**	**5**	**Total**
14	45	36	18	6	119

Table 16 - Percentages of groups in the scheme 9, by land size class

	Scheme	**Group**	**mi %**	**ma %**
CS3	sch9	Fodder crops	25	50
CS3	sch9	Cereals	25	100
CS3	sch9	Legumes		10
CS4	sch9	Fodder crops		25
CS4	sch9	Cereals	25	100
CS4	sch9	Legumes	10	50

Legend: mi=minimum, ma=maximum.

that range from 25% to 50%, in CS3 and are less than 25% in CS4; also, legumes show different percentages: less than 10% in CS3, between 10% and 50% in CS4.

As shown in Table 16, the percentages assigned to the minima and maxima within a scheme are not always compatible.

If the scheme includes only one group, cases 12, 16 and 29 in Table 13, all the area must be allocated to that group, so the minima (mi) equal to 50 is set to 100 ($\widetilde{mi}$), as reported in Table 17 in the first row for schemes 12 and 29.

If a scheme includes more than one group, when the sum of the maximum of a group, plus the minima of the other groups is higher than 100, the maximum (ma) is lowered with Eq. 1 to make it compatible with the minima; the new values are in column in Table 17, which shows initial and correct percentages of groups in 10 schemes.

Tab. 17 - Initial and final percentages of groups in some schemes

	mi	ma	$\widetilde{mi}$ %	$\widetilde{ma}$ %
CS1.sch29.industrial crops	50.00	100.00	100.00	100.00
CS2.sch2.cereals	50.00	100.00	50.00	90.00
CS2.sch2.legumes	10.00	25.00	10.00	25.00
CS2.sch3.uncultivated area	10.00	25.00	10.00	25.00
CS2.sch3.fodder crops	25.00	50.00	25.00	40.00
CS2.sch3.cereals	50.00	100.00	50.00	65.00
CS2.sch8.fodder crops		100.00		75.00
CS2.sch8.cereals	25.00	100.00	25.00	100.00
CS2.sch11.cereals	25.00	50.00	25.00	50.00
CS2.sch11.oilseeds	50.00	100.00	50.00	75.00
CS2.sch11.vegetables		10.00		10.00
CS2.sch12.fodder crops	50.00	100.00	100.00	50.00
CS2.sch16.cereals	50.00	100.00	100.00	50.00
CS2.sch17.meadowland	10.00	25.00	10.00	25.00
CS2.sch17.fodder crops	50.00	100.00	50.00	65.00
CS2.sch17.cereals	25.00	50.00	25.00	40.00
CS2.sch23.cereals	50.00	100.00	50.00	100.00
CS2.sch23.vegetables		10.00		10.00
CS2.sch28.cereals	50.00	100.00	50.00	90.00
CS2.sch28.industrial crops	10.00	50.00	10.00	50.00
CS2.sch32.uncultivated area		10.00		10.00
CS2.sch32.cereals	50.00	100.00	50.00	100.00

Cropping scheme at farm scale

At this stage the schemes are applied to the original farms and integrated with the crops and the surfaces.

Table 18 illustrates one of the farm schemes; each row identifies a group and a crop. The farm ID 260201601590900001 includes four groups of crops: fodder crops, cereals, legumes and industrial crops and is associated with the cropping scheme 1 and is in CS3.

The farm crop mix observed in the FADN database is reported in column 'obs' expressed in hectares.

Table 18 - Farm ID 2602016015909000001 scheme with only the observed crops

		mi		obs	ma	
Group	Crop	ha	%	ha	ha	%
fodder crops	Tot			0.84	2.67	10.00
fodder crops	alfalfa			0.84	2.67	
cereals	Tot	13.33	50.00	16.96	21.34	80.00
cereals	durum wheat	4.34		8.68	17.20	
cereals	hybrid corn	4.14		8.28	17.00	
legumes	Tot	2.67	10.00	2.78	6.67	25.00
legumes	soybean	0.28		2.78	6.67	
industrial crops	Tot	2.67	10.00	6.09	6.67	25.00
industrial crops	industrial tomato	0.61		6.09	6.67	
variable crops	Tot			26.67		

The columns 'mi %' and 'ma %' report the adjusted group percentages calculated in the previous stage. These values multiplied for the total variable crop surface of 26.67 hectares, quantify lower and upper bounds in hectare for the groups 'mi ha' and 'ma ha'.

The lower bound for the observed crops, column 'mi', is calculated, multiplying the crop observed area by the group minimum percentage. In Table 18 durum wheat has an observed surface of 8.68 ha, which multiplied by the cereals group minimum percentage (50%) quantifies in 4.34 ha the crop lower bound; in the same way hybrid corn, which also belongs to cereals, reduces the observed surface to a minimum of 4.14 ha. Soybean drops from 2.78 to 0.28 due to the lower group minimum percentage of 10%; the same happens to industrial tomato. Alfalfa has a minimum area of zero due to the group percentage value.

The upper bound, columns 'ma', for the observed crops is quantified in hectares adding to the previous calculus the minima of the other crops present in the group. If a group includes only a crop, the maximum is set equal to the group surface. This is the case for alfalfa in fodder crops and soybean and industrial tomato in their respective groups. The cereals group, instead, includes two crops. In this case, durum wheat maximum equal to 17.20 ha is quantified subtracting to the maximum surface for the group (21.34 ha) the hybrid corn minimum surface (4.14 ha). For hybrid corn holds 21.34 – 4.34 = 17.00 hectares.

As expected, the crop observed surface is always interior to the calculated range of variation.

The consideration of similar farms provides information to expand the crop mix; in fact, all the crops cultivated by those farms represent a set that is available to each of them. As an example, the crop territorial coverage for this farm is reported in Table 19. On the rows the crops, on the columns the groups. The crop percentages are quantified from the FADN data.

Table 19 - Land use in the territorial context of farm ID 2602016015909000001 (%)

	Groups			
Crops	fodder crops	cereals	legumes	industrial crops
durum wheat		23.10		
tender wheat		37.56		
hybrid corn		23.24		
native corn		2.08		
barley		2.38		
sorghum		11.65		
alfalfa	87.53			
ryegrass	1.65			
silo corn	10.71			
other fodder crops	0.11			
sugarbeet				52.02
potato				15.53
industrial tomato				24.06
other industrial crops				8.29
sweet corn				0.08
chickpea			7.21	
broad bean			0.15	
bean			3.48	
soybean			89.16	
Total	100.00	100.00	100.00	100.00

The previous values, applied to farm ID 2602016015909000001, are reported in the column 'ma %' in Table 20. Multiplying these values by the upper bound of the cereals group, equal 21.34 ha, quantify the maximum crop area in hectares, column 'ma'. The same procedure is applied to all groups in the scheme. Finally, all new crops with a maximum area lower than 0.1 hectares are dropped; this explains why other fodder crops, sweet corn, broad bean are in Table 19 but do not appear in Table 20.

The farm scheme allows reproducing the observed land use and introducing variations matching the farm and the production context.

Table 20 - Cropping scheme for the farm ID 2602016015909000001.CS3.sch1

		mi		obs	ma	
Group	Crop	ha	%	ha	ha	%
fodder crops	Tot			0.84	2.67	10.00
fodder crops	alfalfa			0.84	2.67	
fodder crops	silo corn				0.29	10.71
cereals	Tot	13.33	50.00	16.96	21.34	80.00
cereals	durum wheat	4.34		8.68	17.20	
cereals	tender wheat				8.01	37.56
cereals	hybrid corn	4.14		8.28	17.00	
cereals	native corn				0.44	2.08
cereals	barley				0.51	2.38
cereals	sorghum				2.49	11.65
legumes	Tot	2.67	10.00	2.78	6.67	25.00
legumes	chickpea				0.48	7.21
legumes	broad bean				0.23	3.48
legumes	soybean	0.28		2.78	6.67	
industrial crops	Tot	2.67	10.00	6.09	6.67	25.00
industrial crops	sugarbeet				3.47	52.02
industrial crops	potato				1.04	15.53
industrial crops	industrial tomato	0.61		6.09	6.67	
industrial crops	other industrial crops				0.55	8.29
variable crops	Tot			26.67		

Another example considers the farm ID 2602016015544000000. It is associated with scheme 11, and a total variable crops area of 10.9 hectares puts it in CS2 and (Table 21).

Farm ID 2602016015544000000 has three crop groups: cereals, oilseeds and vegetables. Given the limited surface of vegetable crops in this farm and the percentage with which other crops of this group are observed in the context, only garlic can be introduced in this group, due to the minimum surface requirement set to 0.1 hectare; for the same reason, only a few crops enter in the cereal group.

The procedure on a PC with an Intel(R) Core(TM) i7-4770K CPU @ 3.50GHz, 32.0 GB of RAM, a 64-bit operating system takes less than 3 seconds to generate the cropping schemes and save them in an Excel spreadsheet.

Table 21 - Cropping scheme for the farm ID 2602016015544000001.CS2.sch11

		mi		obs	ma	
Group	Crop	ha	%	ha	ha	%
cereals	Tot	2.72	25.00	4.05	5.45	50.00
cereals	durum wheat				1.19	21.82
cereals	tender wheat	Crop		4.05	5.45	
cereals	hybrid corn				1.09	20.03
cereals	sorghum				0.43	7.94
oilseeds	Tot	5.45	50.00	6.73	8.18	75.00
oilseeds	sunflower	3.36		6.73	8.18	
vegetables	Tot			0.12	1.09	10.00
vegetables	garlic				0.87	79.66
vegetables	other vegetables			0.12	1.09	
variable crops	Tot			10.90		

4. Conclusions

The use of FADN data to identify land use on territorial and farm-scale has so far been a fruitful line of research that we believe deserves further investigation. The use of surface data, together with technical and economic data, opens the way to important operational outlets to analyse policies and intervention measures.

The proposed method is directly applicable across EU member states, where FADN data is a requirement, or in other countries where other data sources on land use by crop at farm scale are available. FADN is recommended for two other main reasons: first, it provides economic data on the same farms, the integrated use of the information available makes economic analyses in agriculture possible; second, FADN identifies crops in much higher details than other EU land use sources, such as the Integrated Administration and Control System (IACS) which since 2018 uses satellites and other Earth observation data and do not include any economic information (Inan *et al.*, 2010; Tomlinson *et al.*, 2018).

The method differs from other approaches such as CropRot (Schönhart *et al.*, 2011), which uses economic information to derives the relative shares of crop rotations with a maximisation process, primarily because only information on the observed land use is requested, and second because the output is not rotation but cropping schemes, flexible structures characterised by ranges of variation and not fixed surfaces.

The method uses in an original way the tables "farms" and "crops", which provide information on the farms and describe land use at farm level for individual crops, to generate cropping schemes for similar farms in a homogeneous production context, identified based on a plurality of criteria, temporal, spatial and productive. Spatial aspects such as regional location, climatic conditions, and location are taken into account, along with specific factors of agricultural activity such as the type of farming practised, the technical-economic orientation, the legal form, the form of management, whether or not the farm is in a disadvantaged area, and the presence of livestock. Only crops which can vary their coverage every year are considered due to the short time horizon adopted.

The method collects the observed crop surfaces at the farms in groups, identified on agronomic and economic criteria; in this way, general land use patterns, called "qualitative cropping scheme", can be identified, which entail the identification of ordinary and extraordinary situations based on their number. The more refined bounded group schemes at the territorial scale, integrated with the land-use coverage generated, can be used in different studies where the aggregate scale is requested. A series of this data over time can describe land use patter over time for homogenous production systems.

A separate output is offered at farm level, where the method quantify cropping schemes that capture possible land-use adaptations. The central hypothesis is that similar farms, the ones located in the same context and with a not too different total variable crops area, can be assimilated to representative farms, can behave similarly, that is, grow the same crops. At this scale, cropping schemes represent a menu of crops, organised into groups, with ranges of variation compatible with the farm surface. This feature makes the schemes suitable for use in mathematical programming models having as independent variables the crop surface area measured in hectares. It should be noted that while all crops in a scheme have an upper bound value, necessary for the model not to be 'unbound'; lower bounds are only present for some of the observed crops; this allows models to reproduce the FADN land use. An important characteristic of the schemes is the consideration of two complementary levels, groups and crops each with own bounds; the former level force the included crops to respect the aggregate value and this acts a strong constrain on the crop mix.

The use of FADN data also provides a plurality of technical-economic information on production processes linked to land use. This feature makes it possible to derive a set of parameters that is homogeneous with the cropping patterns. Their joint application in mathematical programming models makes it possible to assess the adaptation processes that occur in the presence of measures implementing different policies, making explicit the diversity in production systems at the farm level. Initial applications have demonstrated the validity and potential of the method (Bazzani *et al*., 2021). It should be noted that such model integrates more contexts and many representative farms, in this way, complex territorial analysis can be carried out considering in the same time local specificities, which is necessary to capture how different farms respond to external drivers and how cost and benefit are distributed among them.

This method is currently being integrated into a web-based support system that allows the selection of homogeneous production contexts and subsequently the creation of cropping patterns and their use.

Since cropping schemes bounds depend on the observed values in the FADN database, the method provides the possibility to explore expansion or contraction of the crop surface. This can be done by a scenario analysis where variable crops surface may be increased or decreased by a variation coefficient, quantified on available information to simulate realistic changes in production, markets and regulatory framework. This option is suitable to run policy exercises to analyse policies, markets, climate and any drivers of change.

The field of application is wide. Hydrologic models (Gao *et al*., 2017) would benefit from the high level of detail offered, which could entail quantitative evaluation of land-use change effects on hydrologic outcomes, lost when few crops are considered. Carbon footprint, life cycle assessment and environmental studies could benefit from this information source (Bontinck *et al*., 2020); in fact, cropping schemes could be used at more scales by different scientific disciplines with specific research purposes to describe agro-ecosystem in an integrated land-use modelling framework.

Author Contributions

Conceptualisation, G.M.B., R.S.; methodology, G.M.B.; GAMS coding, G.M.B.; writing – original draft preparation, G.M.B., R.S.; writing – review and editing, R.S., G.M.B. All authors have read and agreed to the published version of the manuscript.

Funding

This research has not be funded.

Data Availability Statement

Restrictions apply to the availability of these data. The data were obtained from the Council for Agricultural Research and Economics (CREA) and are accessible at the URL https://bancadatirica.crea.gov.it/Account/Login.aspx with the permission of CREA.

Acknowledgments
We gratefully acknowledge the support of CREA for making the RICA data available to the research team, and Prof. Canavari M. for support, comments and suggestions.

Conflicts of Interest
The authors declare no conflict of interest.

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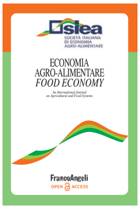
Economia agro-alimentare /
Food Economy

An International Journal on Agricultural and Food Systems

Vol. 23, Iss. 3, Art. 7, pp. 1-22 - ISSN 1126-1668 - ISSNe 1972-4802
DOI: 10.3280/ecag3-oa12756



FADN data to support policymaking: The potential of an additional survey

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Abstract

This paper aims to highlight the potential of a FADN additional survey when payment for organic farming is to be calculated in the rural development decision-making process. In fact, the number of organic farms included in the FADN is often too low to provide consistent results. The analysis is based on a direct survey conducted on a larger number of farms than those included in the FADN continuous sample, considering the organic grape-growing farms. The estimate of the appropriate support payments (amount per hectare) is based on the gross margin methodology which allows additional costs and income foregone at micro-level to be highlighted. The method uses the partial balance sheet of a single crop processing to compare costs and revenues of organic and conventional grape-growing farms and considering both certification and transaction costs.

Article info

Type:
Article
Submitted:
15/05/2021
Accepted:
20/09/2021
Available online:
12/01/2022

JEL codes:
Q12, Q18, Q56, Q58, R11, R58

Keywords:
FADN
Statistics
CAP support
Organic Farming
Support
Payment Schemes
Direct Survey

Managing Editor:
Lucia Briamonte,
Luca Cesaro,
Alfonso Scardera

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Introduction

In the next years, rural areas will face a wide range of challenges and opportunities. The European Union (EU) with the Common Agricultural Policy (CAP) will support the process with its Rural Development Policy, which provides Member States with an envelope of EU funding to manage nationally or regionally under multi-annual, co-funded Rural Development Programmes (RDPs). In Italy RDPs are managed by regions, at least so far (COM/2018/392). As from 2023, all new rural development actions will be integrated into the CAP national strategic plans. Each national plan will focus on key social, environmental, and economic objectives for EU agriculture, forestry, and rural areas. Each RDP is organized by focus areas, measures and actions that are related to their specific subsidies. Each region oversees the payment for each measure included in the financial statement. To fix the level of payments, official data sources are used, among those the FADN database. As is known, it is not designed to cover any research or institutional need and for this reason some critical issues could occur (such as a few organic farms or specific types of farming included which could affect the robustness of some statistical analysis). During the last years, policy makers had to face a more complex system as new agricultural policies and environmental issues demand for integration has grown. To meet current needs, information systems often require adaptation and need to collect additional information also in farm accounting (the beneficiaries are mainly the farms). This was the case for the Friuli Venezia Giulia region which invited the Rural Development Agency (ERSA) and CREA (Council of Agricultural Research and Economics) regional headquarters to enlarge the FADN sample with an additional survey[1]. The aim of the region was is focused on three types of farming: livestock, organic and horticultural. The three-year Project funded by ERSA (2017-2020 with a delay due to Covid-19) applies the Italian FADN methodology to collect and record data. This survey will allow the region to calculate the appropriate payments for the near future (using the integrated FADN sample). This paper aims to provide a path that could be adopted for these calculations looking at the next programming period. The RDP's measure 11 is analyzed and the organic grape growing farms are considered. The wine sector is one of the most important at regional level: It ranks second after the livestock sector, with

1. *CREA-ERSA Project, title:* "Indagini statistiche per l'analisi economica delle aziende agricole del Friuli Venezia Giulia". *Delibera giuntale 497 dd. 25/03/2016, Decreto n. 589 del 21/12/2016, Determinazione direttoriale CREA n. 31 del 26/04/2017, Decreto ERSA n. 597 DD. 10/11/2017, successivi atti aggiuntivi, Determinazione direttoriale CREA n. 291 del 13/07/2020 per emergenza epidemiologica da Covid-19.*

230 million euros, or 20% of the regional agricultural production (Italian Agriculture Yearbook, 2019). The research tries to answer the following related questions: are there any consistent differences between organic and conventional farms' performance that allow the CAP-Rural Development Policy to fund the gap? And what is the amount to be compensated? The core of this paper is the identification of the appropriate payment, based on the gross margin approach. This method, in fact, allows additional costs and income foregone at micro-level for farms adopting similar production process and located in the same area to be highlighted. The implementation of this analytical approach will provide new elements for the debate on the appropriate payment issue using original data (those coming from the additional survey) and considering the organic farming, a topic receiving growing attention from the policy makers.

While the comparison between the performance of conventional and organic farming systems in relation to their environmental impact and productivity has been widely discussed in the literature (Gomiero *et al.*, 2011; Tuomisto *et al.*, 2012; Muller *et al.*, 2017), this paper intends to shed some light on the specific aspect of the revenue and costs analysis.

The article is structured as follows: section one provides a review of the previous studies conducted in the field and a brief description of the organic sector at national and regional level. The methodology and sample data are described in section two. The research results and discussion on data processing are presented in section three, then the paper ends with some conclusions.

1. Background

EU legislation on payments to subsidize farmers with agro-climatic and environmental measures has evolved over time. The first agri-environmental schemes date back to 1992, when the Common Agricultural Policy (CAP) MacSharry Reform introduced the accompanying measures (Berkhout *et al.*, 2018). Regulation n. 2078/92 provided that the subsidies should be based on the commitment made by the beneficiary and the income foregone. With Regulation n. 1257/99, the additional costs were included. During the 2007-2013 programming period (Regulation n. 1698/2005) the wording changed, but the basic principle remained the same. In addition to covering additional costs and income foregone resulting from the commitment, support payments may also consider transaction costs if necessary. In the current programming, payments compensate beneficiaries for most or part of the additional costs and income foregone resulting from the commitments made (Regulation n. 1305/2013). If necessary, they can also cover transaction costs (Ciccarelli *et al.*, 2013) up to a value of 20% of the premium paid for agri-environmental and climate commitments. The impact of the CAP on sustainability is addressed by the literature in agricultural economics and rural studies disciplines, but analyses are often based on case studies and use different methodologies (that produce different results) which are very difficult to compare. Despite this heterogeneity, there is a consensus regarding ineffectiveness in terms of achieving environmental objectives. The proposal for the post-2020 CAP indicates a more flexible and measure-based approach that focuses on paying for the results achieved (Bartolini *et al.*, 2021). The subsidized farmers are affected by the regional administrations decisions as regards the available measures. As is known, the Commission provides an overall framework, a set of measures that are not fully considered in the regional RDPs, which in fact adopt those considered more appropriate to enhance their agricultural systems/rural areas development. The regions make their choices according to the needs of the territory. In this context, Regions are required to provide documents supporting the identification of payments using the available sources. These include FADN, which was mentioned for this purpose in a publication of the Italian Rural Network containing the first guidelines for calculating payments (Italian Rural Network, 2010). To our knowledge there is little in the literature in this field and it mainly refers to methodological guidelines related to both the 2007-2013 and 2014-2020 programming periods (Cesaro *et al.*, 2009; Cagliero *et al.*, 2011; Cesaro *et al.*, 2014; Italian Rural Network 2014, 2015). Following those, there are three important approaches that could be adopted for rural development payments in Italy: counterfactual analysis, hypothetical analysis, and analysis of partial balance sheet. Counterfactual analysis has been adopted in several studies focused on the evaluation of single measures at farm level (on investments' impact or compensatory actions for less-favored areas or to assess environmental or agri-environmental and organic farming constraints) (Ferraro, 2009; Chabé-Ferret and Subervie, 2013; Arata and Sckokai, 2016; Cisilino *et al.*, 2019). The partial balance sheet, instead, requires data at productive process level. The literature on this subject, to our knowledge, is rather poor. This methodology was applied to Friuli Venezia Giulia RDP measures (Cisilino *et al.*, 2014), based on gross margin calculation and the partial balance sheets, which evaluate additional costs and income foregone. That study aimed to support the regional policy decision making process in developing the rural development strategy 2014-2020. In that case, a farm classification by type of farming, economic size, and geographical location was performed. Furthermore, there was no accurate sample information, so it was necessary to use a hypothetical cost and/or income values that caused the economic burden. This methodology, named as standard cost method, has been applied, for example, in the calculation of conservative agriculture measure support payments or in evaluating arable crops management. It provides for the comparison of detailed but hypothetical data using different sources. Some other regions developed similar studies (Abruzzo, Liguria, Marche, Veneto, Sicily). The choice of the most appropriate method – counterfactual or partial balance sheet – depends on topic and on data availability as FADN allows both to be developed. A different approach adopted by Schwarz *et al.* (2011) is the Full Cost of Management (FCM) approach which provides an alternative counterfactual analysis for agri-environmental payments. This method is applicable in some mountain areas where farming systems extensively cultivate lands that are then gradually abandoned because farms do not achieve an adequate level of income. The FCM payment calculation is based on the income foregone plus costs incurred, but because the assumed counterfactual is an absence of agricultural management, and any current agricultural activity is operating at a loss, there is no income to forego, and the payment is entirely costs incurred. In the future the FADN data approach could be augmented by both IACS (Integrated Administration and Control System – EU Commission) and EU Land Use for Agricultural Statistics. Another interesting study by Pascucci *et al.* (2013) that uses FADN data, analyses the RDP measures beneficiaries and provides some evidence of Italian farmers' choices. The analysis distinguishes between farms characteristics (size, specialization, social capital, mechanization, membership of associations, farmer age, etc.) and territorial indicators (development of the agricultural sector, environmental constraints, development of commercial networks) as factors that can affect farm choices. Generally, more attention should be paid to investment, training and marketing in those regions that mainly need to support farms competitiveness, while those presenting high environmental constraints or risks the provision of environmental services would be the most important.

The purpose of our paper is to contribute to the discussion and try to fill in the literature gap on partial balance sheet method based on additional costs and income foregone at micro-level (Cesaro *et al.*, 2014; Rete Rurale Nazionale, 2015). The paper considers organic farming, which is receiving increasing attention at international level. As is known, organic farming contributes to the protection of the environment and climate, long-term soil fertility, high levels of biodiversity and high animal welfare standards (25% of agricultural land under organic farming by 2030, Green Deal, Farm to Fork Strategy). Some aspects of organic farming have potential costs, in particular lower yields, yield stability, water use and working conditions. However, the analysis of these factors must bear in mind that "organic farming with respect to conventional farming varies considerably and is highly dependent on the context" (Seufert & Rarankutty, 2017). The

European Union agricultural organic production has been regulated since 1991. After almost thirty years the EU regulations have been changed and extended to new productions (eg. breeding) and processing (eg. wine). So far, the rules are fixed in the Reg. n. 834/2007 which will be substituted by the Reg. n. 848/2018 in 2022. During the last ten years the area under organic farming has increased in Europe by almost 66% and it now counts for about 13.8 million certified hectares (Eurostat, 2019) or 8.5% of the EU's total Utilized Agricultural Areas (UAA). Italy is one of the leading countries in Europe with Spain, France, and Germany. The 2019 data processed by SINAB (National Information System on Organic Agriculture) highlight that Italy has increased the UAA by almost 2% compared to 2018, reaching 2 million hectares which are 15.8% of the national UAA and there are 80,643 organic producers (+2% with respect to 2018). Three main productions count for over 60% of the total: pasture meadows (551,074 ha), fodder crops (396,748 ha) and cereals (330,284 ha). These are followed by olive (242,708ha) and grape growing (109,423 ha). Friuli Venezia Giulia is one of the smallest Regions in the Northeast Italy with about 1,2 million inhabitants and covering an area of 7,858 square km (it borders Austria and Slovenia). 43% of the territory is mountainous and 19% is hilly with very limited lands for agriculture. According to the Italian Institute of Statistics (Istat) (6th Agricultural Census data, 2010) the total UAA is about 220 thousands hectares (1.7% of the national one). The average size of the 22 thousand farms (–33% with respect to year 2000) is around 10 hectares. More than the half of the total UAA is for arable crops (cereals, industrial and fodder plants) and grapevines. Livestock farms, mainly cattle and pork breeding, are about 14% of the total. The agricultural system is mainly characterized by small farms with little propensity for marketing strategies, but there are also some medium-large sized farms that are well-organized in food supply chains (e.g., pig meat farms belonging to the District of San Daniele ham or the well-known certified vineyards) (Cisilino & Monteleone, 2019). In 2019 the organic agricultural area in Friuli Venezia Giulia is about 12,800 hectares cultivated by 920 operators (-8.2% with respect to 2018). The most important organic crops in Friuli Venezia Giulia are pasture and meadow (28%), fodder crops (18.5%), cereals (13.4%), grape-growing (12.5%), rough grazing (9.3%) and industrial crops (8.8%). Viticulture is one of the most important sectors with the best performance at regional level for production, quality assurance schemes and exports. Furthermore, organic grape-growing has become widespread during the last decade with a constant increase in production (Cisilino & Cesaro, 2009). Considering the last two years of available data, the crops with the highest increase in area under organic cultivation are those of olive and grape growing with +21.3% and 18% respectively.

As the sector under study, it is important to highlight that the performance of organic grape-growing is strongly correlated to climatic conditions and so the regional level analysis is the most appropriate[2].

2. Materials and methods

The Method applied

Evaluating and planning policy interventions for the agricultural sector require increasing information about farms' technical and economic performance at regional level. The assessment process should be based on fair and verifiable calculations, as requested by the Commission (Reg. 1974/2006).

The determining of rural development support payments in Friuli Venezia Giulia is based on the one hand on FADN data, on the other, on a set of qualitative information collected from different sources. In fact, the FADN database is the only available microeconomic source with detailed information on farms' performance and crop/livestock processing, so that its use is appropriate and necessary. But if the aim of the study is too narrow or far from its content, new data collections from an additional survey could be conducted to provide data consistency. In this case, the additional sample provided by the direct survey integrates information in terms of both type of farming and crop processing. The additional regional sample is surveyed to study the economic parameters of farms belonging to three types, including those that apply organic farming methods. An additional database was then created. The method applied in this paper has its roots in a previous and comprehensive study conducted to identify the most suitable payments related to some measures included in the Friuli Venezia Giulia Rural Development Programme 2014-2020 (Cisilino *et al.*, 2014). Given the increased number of organic farms included in the FADN sample due to the additional survey and the differences between organic and conventional gross margin, some interesting results are expected. In the partial balance sheet method, the balance sheets relating to individual production processes are used to compare the costs and revenues of organic and conventional farms to estimate the amount of payment per hectare for

2. Vineyards located in wetlands as Friuli Venezia Giulia show a higher concentration of copper than those in dry areas, which suffer less from the pressure of the disease (Komárek *et al.*, 2010). Copper concentrations in Mediterranean dry climate organic vineyards in southern Italy are much lower than those found in wetlands in northern Italy (Provenzano *et al.*, 2010).

farms adopting organic farming practices. The basis of the calculation is the gross margin, which is the difference between the total gross production and the variable costs related to crop or livestock production, further charged by transaction costs, as established by Reg. EC 1305/2013. The gross margin excludes fixed costs as it is consistent with the provisions of the European Commission Regulation (EC Regulation No 1974/2006). The assets of the agricultural production process balance sheet are defined by gross production, which is the sum of the sales, secondary products, and re-uses values. The latter is determined by applying the most likely market unit value. The specific expenditure, being the passive section of the budget, consists of costs as production activity inputs, intermediate consumption of raw materials, services, and any other additional labor costs. It is assumed that the beneficiary is in a balanced position as far as the labor force is concerned, so that any increase of working units will be managed using temporary workers (Cesaro *et al.*, 2009). Fixed costs, interest (paid and calculated) on land capital and depreciation are not considered in the calculation of gross margin. The difference between the gross margin of treated and non-treated is the level on which to assess the payment's suitability. In calculating payments, the costs of organic certification are also included. These costs are the following: first registration costs (in the check system), maintenance costs and those related to the analyses required by the production specification (Reg. EC 834/07). The certification costs per hectare are calculated using the fees applied by the certifying bodies.

The Rural Development Regulation also allows transaction costs (Reg 1698/2005 and Reg 1974/2006). These can be counted as 20% of the payment. The estimation of transaction costs is based on a specific survey conducted by the authors: farms unions, professional trade organizations and experts were involved. According to the evidence, transaction costs are distinguished into three classes (small <5 ha, average 5-10 ha, large > 15 ha) as the dimension of the area under treatment is considered. The transaction costs for organic farming consist mainly of costs incurred by the farmer in managing the funding application, including those related to the time spent to fill it in and the relative hourly work cost. For time assessment, the cost of a skilled agricultural worker has been considered using both hourly rate and severance package applied to agricultural workers by the sector's collective agreement at regional level.

The Dataset used to identify the support payment

The Dataset collects 1,637 accounts, 1,266 of which belong to the online Friuli Venezia Giulia FADN Database (FADN FVG) and 371 from CREA-

ERSA additional survey. The three-year's survey ended in 2020, six months later than the scheduled time due to Covid-19 epidemic. The activities were organized in three phases: a) a preliminary contact (by telephone) to arrange meetings between interviewers-farms; b) direct survey/data collection; c) information checking and processing. As expected, some failures occurred: some of the farms included in the first list were replaced. Data monitoring showed an average drop rate of 35% during the whole period. The survey, conducted in the four provinces of Friuli Venezia Giulia, shows a greater concentration of farms in the provinces of Udine and Pordenone, those more suited to agriculture. The project was carried out as follows: first of all a desk data check and harmonization of databases. Starting from the lists of farms provided by ERSA, three samples were identified following three criteria: geographical location, farm-size and public funding requirements to access the provisions of the RDP. Then three samples of farms belonging to the organic, horticultural and livestock sectors were then produced. To conduct the survey using the FADN-CREA methodology, specific training was provided to interviewers.

The dataset therefore consists of the two merged databases: the Additional Survey database (ADDS) and the Friuli Venezia Giulia FADN database (FADN FVG). Both use the Italian FADN-CREA methodology on the time series 2016-2018. The same data collecting method was applied in both surveys, so the dataset is considered as a single homogeneous source of data. The following data stores were analyzed: a) Crops, which includes variables related to each single production process (one to many data); b) Farms, which includes structural data at farm level (one to one data); c) Certification, which includes information related to the quality production schemes (one to many data). The Italian FADN data include information additional to those required by the European Commission. For example, in the Italian Crops data store revenues and costs are recorded at single process level, so this allows the gross margin for any different crops cultivated by the farm to be obtained. This is crucial for the analysis presented here. Furthermore, the Certification data store includes organic farming information, even if there is not any specification about the single process. Therefore, it is assumed that farms with organic certification are entirely organic. The data processing is performed considering a three-year dataset, applying the same method used in Cisilino *et al.* (2015). The gross margin is calculated per hectare. The production processes with a positive gross margin are considered, as well as those having a positive production value. Certification costs are identified using the tariff of certifying bodies (e.g. ICEA). In the current analysis, however, since the additional sample of farms is made up of organic farms, specific attention is paid to certification. The transaction costs consider a re-valuation of the components according to the ISTAT annual rate (2018).

The value is then broken down according to the area covered by the crop. This is consistent with the administrative burden arising from the CAP and published by the European Commission (European Commission, 2019), as far as the application submission costs incurred by farms are concerned. All items determining administrative costs are considered and some farmers have been also interviewed. The paper tries to highlight how private transaction costs depend on several factors, distinguishing between internal costs (i.e. the value of the time spent by farmers, their families and employees to meet administrative obligations to submit applications), and external costs (i.e. costs for outsourced services). In the first case, the amount is affected by the farm size and its structure (livestock, arable land, permanent crops, mixed crops), by the number and types of funding support received, as well as the total support payments. Furthermore, the administrative governance (national or regional level), as well as the development level of digitalization, has a great impact on outsourced services costs (European Commission, 2019).

3. Results

The organic sample surveyed main results

The organic sample surveyed by the project includes 268 farms, 130 of which belong to the Additional Data Set (ADDS). The analysis provides a structural and economic overview of both of the FADN FVG and the ADDS. The farms were classified through altimetry ranges and economic size categories. In both samples only two farms show a Standard Output (SO) higher than €500,000, mainly due to the farm-size of Friuli Venezia Giulia region (small-medium seized). In the ADDS sample there is a greater number (25%) of small companies (SO between €8,000 and €25,000) attributing greater representativeness to these farms. The territorial location, on the other hand, shows a concentration of organic farms on the plains (49% in the ADDS, 54% in the FADN FVG), which gradually decreases as altimetry increases.

According to data, the average Utilized Agricultural Area (UAA) is highest in the FADN FVG sample, 34.42 hectares, while it is 16.50 hectares in the ADDS sample. The irrigated UAA on total UAA of both samples is equal to 25% of the surface (lowland organic farms are those that irrigate most, about 55% of the UAA).

The average workforce endowment slightly exceeds 2.00 Annual Work Units (AWU) per farm, about 70% of total work is done by the farmer and his family. The largest farms of the samples (included in the fourth economic size class with a SO between €100,000 and €500,000) have the largest workforce (3.95-5.9 AWU).

Table 1 - Organic sample: structural and economic characteristics. Average values at farm level, time series 2016-2018 (ADDS and FADN FVG)

	Number of cases	**UAA Utilized Agricultural Area**	**AWU Annual Work Units**	**TO Total Output***	**CC Current costs**	**FVA Farm Value Added**	**FNI Farm Net Income**
	n.	**ha**		**€**	**€**	**€**	**€**
ADDS Organic Sample							
Altimetry							
Mountain	12	17.20	2.0	75,718	33,711	42,007	36,201
Hill	54	19.85	2.0	187,116	59,309	127,807	105,862
Plain	64	13.55	2.3	160,839	80,864	79,975	42,176
Economic Size							
8,000-25,000	39	3.25	1.0	113,177	72,110	41,066	27,510
25,000-50,000	32	7.95	1.4	79,253	23,256	55,997	41,840
50,000-10,000	26	12.01	2.5	120,826	43,070	77,756	47,554
100,000-500,000	31	44.75	4.0	314,774	117,438	197,336	139,939
> 500,000	2	32.36	3.0	728,535	232,790	495,745	431,980
Total (ADDS)	130	16.50	2.15	163,896	67,558	96,339	68,079
FADN FVG Organic Sample							
Altimetry							
Mountain	18	17.97	1.4	33,117	15,035	18,082	15,603
Hill	32	18.44	2.4	180,611	73,100	107,511	72,791
Plain	58	48.33	2.1	222,942	93,750	129,192	82,307
Economic Size							
8,000-25,000	18	7.76	0.8	30,542	12,338	18,204	10,481
25,000-50,000	35	13.16	1.2	45,341	18,437	26,904	18,053
50,000-100,000	20	18.21	2.0	148,060	41,291	106,769	92,352
100,000-500,000	33	46.01	3.4	311,532	146,201	165,331	104,028
> 500,000	2	617.00	5.9	1,963,928	764,764	1,199,164	641,733
Total (FADN FVG)	108	34.42	2.06	178,762	74,512	104,249	68,370

* In the Italian FADN the Total Output also includes the income from Other Gainful Activities (OGA) directly related to the farm.

Source: own data processing from CREA-ERSA direct survey.

The economic results make it possible to draw important conclusions relating to the farm's income statement (Table 1). The Total Output (TO), which includes the income of Other Gainful Activities (OGA) is between €164,000 and €178,000. More than 80% of TO is represented by the agricultural Gross Saleable Production (GSP) (over €140,000) and the remaining 20% comes from OGA. Current costs (CC) affect the TO by 41%. Farm net income (FNI) is about €68,000 for both samples. Above-average values are those referring to hill farms and larger economic size farms.

The analysis of the two samples highlights some differences but also several similarities, especially in the results. This confirms that the structure of the farms has similar characteristics, reinforcing the solidity of the results.

Table 2 - Main crops surveyed

Organic crop species	**FADN FVG**	**ADDS**	**Dataset**
	n.	**n.**	**n.**
Grape growing – quality wine	31	39	70
Alfalfa	37	30	67
Soja	37	23	60
Polyphyta lawn	28	29	57
Corn	21	30	51
Permanent meadows and pastures	28	23	51
Potato	9	40	49
Barley	24	21	45
Apple	8	36	44
Wheat	26	16	42
Vegetable	21	17	38
Tomato	4	26	30
Radicchio	1	28	29
Onion	2	26	28
Zucchini	2	21	23
Sun flower	16	6	22
Olives for oil	2	20	22
Spelt	5	15	20
Grape growing – common wine	8	12	20
Actinidia (Kiwi)	8	10	18
Dry pea	6	12	18
Cauliflower	1	14	15
Aubergine	1	14	15
Cabbage	1	13	14
… (other crops)	…	…	…
Total organic crop	532	820	1,352

Source: own data processing on CREA-ERSA survey data.

The percentage of FADN FVG organic farms subsidized by the RDP's organic farming measure is 8.5% (Pascucci *et al.*, 2013), when considering the dataset used in this study (FADN FVG and ADD survey), the percentage increases to 14.5%. The organic crops recorded by the dataset are 1,352 or 18% of the total crop production processes (7,510), while the conventional processes are 6,158. Aggregating the data by type of cultivation, the number of organic crop species investigated is 110.

Table 2 shows the increase in the number and varieties of crops. The additional survey gives an important contribution especially on permanent crops - grape growing, apple tree, actinidia, olive tree, and on horticultural crops. Grape growing for organic quality wine is the most represented crop within 70 observations.

The support payment for organic grape growing

The support payment is provided using the production process method, identifying the differences between organic and conventional gross margins and transaction costs as established by Reg. EC 1305/2013. This allows organic additional costs and income foregone to be quantified.

Table 3 - Estimated payment - Grape growing (quality wine)

Average data	**Conventional**	**Organic**
n.	486	70
UAA	7.0	8.4
Yield (tons/hectare)	12.9	8.4
Total Output (€/tons)	719.9	956.6
Total Gross Production (€/hectare)	9,273	8,016
Total Variable Costs (€/hectare)	2,153	2,423
Certification Costs (€/hectare)		131
Gross Margin (€/hectare)	7,120	5,594
Transaction Costs (€/hectare)		93
Δ Gross Margin		1,527
Transaction Costs		93
Additional costs and income foregone		1,619

Source: own data processing on CREA-ERSA survey data.

Comparison between organic and conventional farming is a very interesting field of research started in the late 1990s with the first writings of Lampkin (1994) and then of Offermann and Lampkin (2006): since then, many approaches have been applied to highlight differences between the two systems, mainly to find out the potential gap to be compensated. The evaluation of organic versus conventional farming should consider the appropriate time horizon as this plays an important role when assessing the effects on soil fertility (effects can be observed some years after conversion). In this case, it was not possible to collect any data on the positive environmental effects coming from organic farming. However, these could be a very interesting further development of this study. The limit coming from the comparison of the two different farming system is less important in specialized viticultural farms where the profitability of the vineyard is not far from farm profitability. Still, significant differences may be observed between farms not processing and processing wine.

The results of the estimate confirm the difference between organic and the conventional farming at least for the grape growing sector. In fact, the results show the lower yield and lower gross margin per hectare of the organic grape growing. Although the total output per tons is higher for organic farms, this fails to compensate for the productivity loss. In general, grape growing gross production is quite high in Friuli Venezia Giulia. Looking at some other Italian regions, similar results have been provided by data processing as far as the total gross production is concerned (Liguria and Veneto RDPs, Annex, changes 2020 and update 2017). Furthermore, in the last decade there has been a significant increase in the spread of Glera variety to produce Prosecco wine (Cisilino, 2018; Mipaaf, 2016), which is characterized by higher yields per hectare (in the production disciplinary of Prosecco DOC in Friuli Venezia Giulia the yield is fixed in 18 tones, while in Veneto region the disciplinary for DOCG Conegliano-Valdobbiadene yield is 13,5 tons) than the limits required for other regional DOC varieties (an average value of 12 tones per hectare is normally assumed). Organic farming shows higher variable costs which also include certification costs. The certification costs per hectare have been defined using the rates published by the Institute for Ethical and Environmental Certification (ICEA). The basic tariff, the variable component and any extraordinary investigations required by the certification procedures have been considered. According to the ICEA tariff, for example, the certification cost for tree crops corresponds to €150.00/year plus €55.00 in the case of apple trees and plus €30.00 in the case of grape growing (Abruzzo RDP, update, 2018). In our analysis, it was possible to process the average value of the certification costs recorded in the dataset. The conventional and organic crops gross margin delta increases when transaction costs are also included. These costs are consistent with what has emerged in other Italian regions (Marche RDP 2014-2020, Revision 2018; Sicilia RDP 2014-2020, Revision 2018).

The analysis presented in this study shows some limitations; the main ones are the following: i) the paper is focused on a single measure and on a single type of farming (general validity problem); ii) an additional survey was funded to overcome the FADN lacks in terms of the relatively low numbers of farms within a specific type of farming (funds' availability problem); iii) a single Italian region is considered (restricted area under study problem). To extend the validity of these results, further analyses should be applied to both other measures/types of farming and territorial context.

4. Conclusions

The analysis presented in this paper provides useful information for the rural development decision-making process, showing a method to identify the appropriate payment for RDP's organic farming measure, based on the gross margin method. To achieve this, a FADN additional survey is considered crucial and necessary, mainly to avoid some FADN limitations in terms of low number of organic farms included in the continuous database. The importance and usefulness of an integration of information by an additional survey that could enlarge the continuous FADN survey, allows on the one hand to widespread information about the Italian methodology – which is richer in information than the standard requested by the Commission – on the other to highlight the importance of filling some gaps in the database in terms of response to specific issues. In this case, the increased number of observations by crops allows a more robust result to be obtained as far as the calculation of organic grape growing payment is concerned. Furthermore the results confirm those of previous studies developed by some Italian Regions (Abruzzo, Liguria, Marche, Sicilia and Veneto). Even if the data processing has been performed for only one crop, this should be considered as a good first step, a promising one towards all the other crops. Furthermore, FADN is designed to be representative of the regional farming systems, but very small farms are not included. Instead, as is known, those are the farms that find involvement in organic farming and be less profitable with respect to large farms due to the fixed transaction costs as in the case of the agri-climate and environmental schemes (Bartolini *et al.*, 2021). The additional survey tried to fill in this gap and included a large number of small organic farms. However, this study has several shortcomings as regards the data used, which are project specific, therefore difficult to be applied elsewhere without funding. When discussion focuses on data availability, one of the most important issues to be addressed is the harmonization of statistics: this would require above all the cooperation among Public Institutions (both related to Research and Governmental Institutions at EU, national and regional level) whitin a view of common use of available resources (costs reduction) as well as better data quality assurance. Although the transition to a more results-oriented model is desirable to better understand the link between payments and environmental performance (Reg. EU 2020/2220), the current methodologies as well as data collection systems, seem not to be satisfactory, as they cannot ensure the application of results-based payments. Furthermore, in most cases ex-post analyses are developed, while on-going monitoring and above all a different evaluation process especially for organic and environmental measures schemes would be necessary.

Aknowledgements

The authors thank the Friuli Venezia Giulia Agency for Rural Development (ERSA) for providing useful information. The research was funded by ERSA, Project developed during 2017-2020 period (Friuli Venezia Giulia Resolution 497 dd. 25/03/2016, Decree n. 589 del 21/12/2016, CREA Directorial Act n. 31, 26/04/2017, ERSA Decree n. 597 DD, 10/11/2017, subsequent additional acts CREA Directorial Act n. 291, 13/07/2020 for Covid-19 epidemiological emergency.

The authors thank the reviewers for their valuable comments and suggestions that were very helpful for revising and improving our manuscript.

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Economia agro-alimentare /
Food Economy

An International Journal on Agricultural and Food Systems

Vol. 23, Iss. 3, Art. 8, pp. 1-19 - ISSN 1126-1668 - ISSNe 1972-4802
DOI: 10.3280/ecag3-oa12758

Modeling change in the ratio of water irrigation costs to farm incomes under various scenarios with integrated FADN and administrative data

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Abstract

The Water Framework Directive 2000/60/CE (WFD) of 2000 was issued by the European Union (EU) to prevent water deterioration and promote its restoration. It introduced a water pricing policy in the agricultural sector that is based on a 'polluter-pays' principle. To date, some Member States have yet to comply with the pricing requirement for two main reasons: water cost estimates, as defined by the WFD, are particularly complex and difficult in the agricultural sector and farmers in marginal economic and environmental contexts may be unable to bear higher water costs. In Italy, water services are managed by regional administrations that also set irrigation water prices. This research estimated the effect of changes in irrigation water costs borne by farmers on farm incomes in a case study in the Aosta Valley Region where extensive farming is practice in a significantly naturally-disadvantage area. The analysis was modeled using four cost scenarios with economic data from the Farm Accountancy Data Network (FADN) integrated with irrigation water cost data provided by a regional administrative database. Estimated water costs averaged 2.65% and 1.06% of farm incomes, depending on the presence or absence of regional subsidies. Water costs represented higher income proportions on specialized grazing livestock farms, which is the predominant type of farming in Aosta Valley. These results raise concerns for WFD implementation, in particular, in mountain and agriculturally-disadvantaged areas with extensive and less-profitable farming.

Article info

Type:
Article
Submitted:
14/05/2021
Accepted:
15/09/2021
Available online:
12/01/2022

JEL codes:
Q12, Q15

Keywords:
Water Framework Directive
Irrigation
Farm income
Farm Accountancy Data Network

Managing Editor:
Lucia Briamonte,
Luca Cesaro,
Alfonso Scardera

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Introduction

In recent years, the European Union (EU) has utilized political actions to not only reduce the pressures on environmental resources, but also to encourage their restoration. For example, the Water Framework Directive 2000/60/EC (WFD) is directed at ensuring good quality water is available to meet the economic and social needs of Member States (MSs) (European Commission, 2019). The Directive was innovative as it introduced a uniform pan-EU water pricing policy for saving water and recovering service costs based on the 'polluter-pays' principle (WFD, Art. 9). It requires each Member State (MS) to set water charges by economic sector, such as agriculture, manufacturing, transportation, and so on. While the last report on WFD implementation (European Commission, 2019) indicated that some MSs have upgraded their water pricing policies, others have yet to meet the original requirements. Shortcomings are most often attributed to the complexity of estimating costs as defined by the Directive for the agricultural sector (Zucaro, 2014).

According to European guidelines (European Commission, 2000), the water pricing policies must include three cost types: i) 'financial costs' for water management and provisioning services, including operating, maintenance, and capital costs; ii) 'environmental costs' for environmental/ecosystem damage resulting from poor water use; iii) 'resource costs' or alternative water use opportunities lost to exploitation or depletion (European Commission, 2000; WFD, Art. 9). While financial costs are relatively easy to define, environmental and resource costs are less straightforward and lead to estimation problems (Zucaro, 2014). Nonetheless, Reg. (EU) 1303/2013 – laying down common provision on the European Structural and Investment Funds for the 2014-2020 programming period –, introduced the ex ante conditionality for accessing European funds. Water resource ex ante conditionality establishes: i) a water pricing policy which provides adequate incentives for users to use water resources efficiently, and ii) an adequate recovery of the costs of water services at a rate determined in the approved River Basin Management Plans.

In Italy, water services are managed regionally and administered by the Irrigation and Reclamation Consortia and the Consortia for Land Improvement. Water sector pricing estimates are set at the regional level. The criteria for estimating environmental and resource costs for the sectors was clarified when the Italian Ministry of Environment adopted the WFD through Ministerial Decree no. 39/2015. The Decree also explained Directive exemptions for "disproportionate costs" and other circumstances (WFD, Art. 4). According to the Decree, a disproportionate cost is one that exceeds its benefits or one that is beyond a party's ability and willingness to pay.

In many EU economic and environmental contexts, affordability limits implementation of the Directive, as farmers may not be able to bear higher water costs. The Aosta Valley Region represents one such region. Almost entirely mountainous and nearly completely constrained by natural and environmental factors, the EU considers most of its territory as being a "disadvantaged area" for agriculture. In this valley, irrigation water services are provided subject to peculiar social and cultural habits and practices that make it difficult to establish water price policy based on European guidelines. In this case, the consortia costs are largely borne by the Region, while only a small amount are paid by users through a special water payment called *ruolo*. The *ruolo* is defined by the Regional Law no. 3/2001, which provides that consortia may impose contributions to the users of irrigation services, whether they are farmers or non-agricultural users (e.g., residents with gardens). The law specifies that such payments are meant to contribute to compensate management, operating and ordinary maintenance costs borne by the consortia (Law no. 3/2001, art. 13). Environmental costs and resource costs are not included, therefore the EU claims that the *ruolo* does not meet the WFD guideline and that the current regional water policy is not suitable under the Directive. Moreover, these payments are often very low or go unpaid as the consortia members work voluntarily to maintain their territorial water network in lieu of payment through *corvées* (Francois and Garello 2004; Seroglia and Zucaro, 2009; Florio, 2013).

The non-conventional irrigation water pricing in the Aosta Valley Region raised questions as to how it might comply with WFD guidelines and how costs might be borne by farmers. For these reasons, the research was aimed at: i) estimating the proportion of farm incomes used to cover irrigation water costs, and ii) developing of various scenarios from which water costs can be estimated, to provide different calculation methods that policymakers might adopt to allocate costs.

Several authors have considered the economics of water policy pricing from various perspectives. Massarutto (2003) studied an economic approach like that sought by the WFD, analyzing the trade-off between economic efficiency and environmental sustainability in water pricing policy. Gòmez-Limòn and Riesgo (2004) proposed a mathematical programming model to evaluate the economic and social impacts of irrigation water pricing policy on heterogeneous farmers. Bazzani *et al.* (2004 and 2005) tested a farm-level model under different scenarios to identify suitable policy instruments for WFD application. More recently, Galioto *et al.* (2013) developed a methodology using Farm Accountancy Data Network (FADN) information to assess WFD guideline-based disproportionate costs to estimate agricultural income losses in the Emilia-Romagna Region. The FADN database has previously been used to analyze similar topics: identification of an efficient irrigation water management for rescue protection efforts under the Common Agricultural Policy (CAP) (Capitanio *et al.*, 2015); evaluation of CAP and WFD coordination on water use savings (Kampas *et al.*, 2012); evaluation of the impact of taxes on daily farm income volatility (Vrolijk *et al.*, 2020).

Two features distinguish this study from those above. First, the work concerns the territorial peculiarities of the Aosta Valley Region, which is characterized by significant natural disadvantages and extensive farming. Second, various cost scenarios were considered using integrated data sourced from the FADN (economic data) and from regional administrations (irrigation water cost data).

1. The study area

The Aosta Valley is an Italian Region located in northwestern Italy. It extends to the inner side of the Alpine chain, between the Graie and Pennine Alps. Its mainly-mountainous territory is typically divided into three areas: Upper, Middle, and Lower Aosta Valley. It includes the entire west to east alpine stretch of the Dora Baltea River that flows into the Po River, branching off along its route in a large number of tributaries. Almost all of the 700 natural and artificial lakes in the area lie in the Dora Baltea basin and cover a total of 9.5 km^2. The orography of the Region characterizes its climate. At higher altitudes, the summers are short while the winters are rigid and long. Downstream, poor ventilation makes the summers hot and humid and in winter the temperature drops below zero. The precipitation profile includes two maxima during the spring and autumn seasons and two minima during the summer and mostly snowy winter (RAVA, 2019). Generally, annual precipitation averages 1000 mm, although the topography can cause large territorial differences. For example, high mountains can hamper air mass circulation and cause an arid central area where rainfall averages about 550 mm per year. The low annual rainfall, especially in summer, makes irrigation essential for agricultural production. On average, the regional water consumption for the sector is about 770 million m^3/year. Water availability to meet irrigation needs during summer in the Region is highly influenced by snow and ice melt (RAVA, 2019; Seroglia and Zucaro, 2009).

The regional Utilized Agricultural Area (UAA) spans about 56,000 ha, 15,000 ha (26.8%) of which are irrigated (Istat, 2010). Nearly the entire UAA (about 54,000 ha, 27.7% irrigated) is devoted to extensive grazing due in part to the pedoclimatic conditions that are unfavorable to other types of cultivations. In addition, area farms have specialized in dairy cattle for Fontina, a PDO cheese, which requires a largely diffuse zootechnical sector.

The remaining area is cultivated with permanent crops, mainly vineyards, followed by orchards, mostly for apple production (Trione, 2020).

Irrigation water management for agricultural purposes is administrated through nonprofit private Land Improvement Consortia (LIC). Of the 176 LIC in the Aosta Valley Region (Regione Valle d'Aosta, 2021), most are responsible for managing irrigation networks. A smaller share function exclusively as land improvement bodies. The area under LIC administration includes about 177,000 ha, which accounts for more than half of the regional surface. In most cases, LIC were started by farmers who self-organized to manage irrigation activities, and their administrative and technical management activities continue to be performed voluntarily by members today. The high number of LIC allows them to address local needs, but it makes it difficult to develop a homogeneous management – and uniform water irrigation policy – throughout the territory (Seroglia and Zucaro, 2009).

2. Materials and methods

Data sources

As mentioned, this study attempts to enhance the information available on the ratio of water irrigation costs to farm incomes (water costs-to-income ratio). The data used in this study were collected from two sources: the Farm Accounting Data Network (FADN) economic data, compiled from a survey of farms, and the Spatial Data Infrastructure (SDI), that houses LIC regional cost data. The data sourced from the Aosta Valley FADN comes from its annual survey of about 250 farms. The sample includes the main types of commercial farms, chosen by Economic Size (ES) and measured by total Standard Output (SO)[1]. About 1,000 variables on physical and structural data (location, crop areas, livestock numbers, labor force, etc.) as well as economic data (revenue, redeployment, final stocks, purchases of technical equipment, and others) and financial and balance data (debts, credits, public aid, production rights, acquisition and disposal, etc.) are collected through a survey submitted to each farm (FADN, 2018). SDI is a logically-structured administrative database containing territorial, environmental, and socio-economic information on the Aosta Valley Region (Regione Valle d'Aosta, 2018). The SDI provides in single database spatial information concerning environment, economy, cartography, structures and transport.

1. The Standard Output (SO) is the average monetary value of the agricultural output at farm-gate price of each agricultural product (crop or livestock) in a given region. It is calculated by MSs per hectare or per head of livestock, by using basic data for a reference period of 5 successive years.

Water costs-to-income ratio was obtained by creating a cross-database from the two sources, including total cost of LIC sourced from the SDI (used to calculate a water pricing proxy) and farmers' income sourced from FADN.

Analysis design

The methodology adopted to assess the water costs-to-income ratio integrates Italian FADN economic data and LIC cost data as a proxy for water price.

Four steps comprise the analysis undertaken (Figure 1):

1. Select a sub-sample of farms and variables in the Aosta Valley FADN database;
2. Select LIC data from SDI database and define a water pricing proxy;
3. Construct a common dataset using data from the SDI database;
4. Define evaluation scenarios.

Figure 1 - Diagram of methodological approach

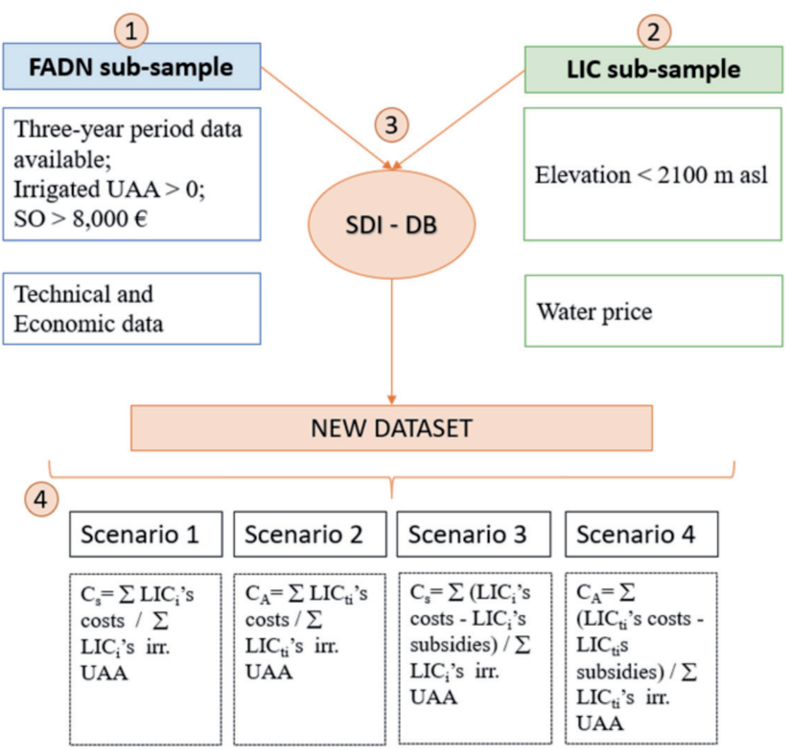


Table 1 - Description of structural and economic variables used for simulation

Variables	Description
Utilized Agricultural Area (UAA)	Total utilized agricultural area of holding expressed in hectares
Irrigated UAA	Hectares of irrigated UAA
Farm Net Income (FNI)	Remuneration to fixed factors of production of the farm (work, land and capital) and remuneration to the entrepreneurs' risks (loss/profit) in the accounting year
Water costs	Known costs of water input per hectare in one year

Source: FADN (2018)

In the first step, a sub-sample of farms were selected from 2016, 2017, and 2018 from the Aosta Valley FADN database. Selection criteria were as follows: (1) farm data must be available for each year of the three-year period; (2) farms must have irrigated UAA; (3) the SO of farms must be at least 8,000 € (minimum to be classified as commercial in Italy) (FADN, 2018). Based on these criteria, 191 farms were selected. Next, a set of structural and economic variables was selected from the FADN database for simulation (Table 1). Additional variables were assigned to aggregate the selected farms into different categories/classes for result interpretation (Table 2). In order to obtain significant results, categories/classes were included in the analysis if the relevant sample size exceeded five units. Table 3 shows the descriptive statistics of the structural and economic variables used for the simulation.

In the second step, eligible expenses and subsidies were selected from regional LIC farms located below 2,100 m asl in a potentially-irrigable area. This decision was made to include consideration of the largest area of fertigated pastures during the 2016-2018 three-year period. A total of 2,833 farms fit these characteristics and belonged to 127 different LIC. A conservative estimation was made, assuming the worst-case scenario where farmers have to bear all LIC costs (i.e., management, operational, and regular maintenance of land improvement work costs) Hence, for each LIC, total cost data were extracted and considered as a proxy for water price. Then, an average unit cost per farm-associated LIC was calculated.

During the third step, a dataset was built of both FADN and SDI variables that linked each FADN farm with its associated LIC. Next, this linkage allowed a newly-derived FADN-based variable (net income) to be calculated in which water cost data are LIC-based.

The final step in the method defined different scenarios to assess the effect of water cost on farm incomes. They were created by linking water

Table 2 - Description of the variables used to classify the selected farms into different categories/classes

Variables	**Description**	**Categories/Classes**
Economic Size (ES)	Defined as the total Standard Output (SO) of the holding expressed in euro	Small = 8,000 – 25,000 € Medium-Small = 25,000 – 50,000 € Medium = 50,000 – 100,000 € Medium-Large = 100,000 – 500,000 € Large = > 500,000 €
Type of Farming (TF)	Classify the farms by their typological affinities that each agricultural activity presents with other. The TF are defined in terms of the relative importance of the different enterprises on the farm. Relative importance is itself measured quantitatively as a proportion of each enterprise's SO to the farms' total SO	Specialist field crops Specialist horticulture Specialist permanent Crops Specialist grazing livestock Specialist granivore Mixed cropping Mixed livestock Mixed crops-livestock
Utilized Agricultural Area (UAA)	The holdings are distinguished by classes according to the number of UAA hectares	< 5 ha 5-15 ha 15-40 ha > 40 ha

Source: FADN (2018)

Table 3 - Descriptive statistics of the variables used for simulation

	Mean	**Std. Deviation**	**Min**	**Max**
UAA (ha)	73.26	103.05	0.55	487.14
Irrigated UAA (ha)	10.31	13.08	0.21	90.02
FNI (€)	52,493	71,296	–16,163	788,871
Added value (€)	75,998	101,637	3,750	893,113

Source: our elaboration on FADN data (2018)

costs calculated in step 2 with farm income variables extracted in step 1. Scenarios were differentiated based on the type of water costs assigned to each farm – average or specific costs. Average costs (C_A) were calculated as the ratio between the sum of management costs across all the LIC and the total irrigated UAA (from LIC data), while specific costs (C_S) were calculated as the ratio between the sum of management costs of the LIC to which the farm belonged and its associated irrigated UAA. In addition, water costs were estimated both with and without consideration of regional subsidies. In the first case, costs were calculated absent public support recognition (gross subsidies). In the second case, costs were calculated taking public support into account by discounting the relevant grant (net of subsidies). This resulted in the farm irrigation cost being the product between the irrigated UAA and the unit cost as described above. Four scenarios were identified:

Scenario 1: C_S is used as a proxy for water pricing. Water costs are allocated to each farm based on the irrigated UAA extracted from the Aosta Valley Region SDI. This scenario assumes a water cost borne by farms based on the specific costs to manage the corresponding LIC.

Scenario 2: C_A is used as a proxy for water pricing. An average unit value of 153.65 €/ha was employed, calculated as the ratio of total management costs of all LIC to total hectares of irrigated UAA. In this scenario, a fair cost distribution is estimated for the entire territory, regardless of the corresponding LIC.

Scenario 3: C_S, discounted for regional subsidies (net of subsidies), is used as a water pricing proxy. These subsidies are estimated to be 60% of LIC-incurred management costs.

Scenario 4: C_A, discounted for regional subsidies (net of subsidies), is used as a water pricing proxy. The average unit value equaled 61.46 €/ha, calculated as the ratio of total management costs of all LIC (net of subsidies) to total hectares of irrigated UAA.

Sample description

The 191 farms selected from the FADN database were categorized according to the classes of Economic Size (ES), Type of Farming (TF), and Utilized Agricultural Area (UAA). For ES, the farms were distributed relatively equally across the first four ES classes: Small (20%), Medium-Small (26%), Medium (29%), and Medium-Large (25%). Farms with a SO value of more than 500,000 € (Large) were excluded from the sample (Table 4). As expected, the Farm Net Income (FNI) grew as the ES increased (average value was approximately 53,000 €). The average physical farm size was about 73 ha, of which nine ha (13%) were irrigated. The share of irrigated area decreased as the ES increased (from 72% in Small farms to 9% in Medium-Large farms).

In the case of TF, the majority of farms were specialized grazing livestock farms (dairy farms); the remainder were specialized permanent crop farms (either vineyards or orchards) (Table 5). Livestock farms produced

Table 4 - Farm structural and economic average data by Economic Size (ES) class

ES	Sample size (n)	UAA (ha)	Irrigated UAA (ha)	Irrigated UAA/total UAA (%)	FNI (€)
Small	39	3.32	2.38	72	16,160
Medium-Small	49	19.56	4.81	25	38,822
Medium	55	65.49	9.89	15	51,172
Medium-Large	48	193.80	17.95	9	97,482
Total	**191**	**73.26**	**9.10**	**12**	**52,493**

Source: our elaboration on FADN data (02/09/2020)

Table 5 - Farm structural and economic average data by Type of Farming (TF)

TF	Sample size (n)	UAA (ha)	Irrigated UAA (ha)	Irrigated UAA/total UAA (%)	FNI (€)
Specialist field crops	4	4.43	4.16	94	30,564
Specialist horticulture	2	0.81	0.64	80	37,724
Specialist permanent crops	51	3.94	2.98	75	65,379
Specialist grazing livestock	115	111.85	12.71	11	49,305
Specialist granivore	0	0	0	0	0
Mixed cropping	6	4.41	4.36	99	76,546
Mixed livestock	0	0.00	0.00	0	0
Mixed crops-livestock	13	67.91	5.49	8	28,060
Total	**191**	**73.26**	**9.10**	**12**	**52,493**

Source: our elaboration on FADN data (02/09/2020)

milk that was processed into PDO fontina, which yielded a reduced net income compared with less-represented TFs. The farms in the sample that specialized in field crops and horticulture numbered fewer than the five-unit threshold, so these TFs were excluded from the analysis.

In Table 6 the farms are classified in four UAA classes. The largest group is that with an average physical size higher than 40 ha, in this case the ratio between irrigated UAA and total UAA is very low. The opposite goes to farms with less than 5 ha of UAA, where almost the whole area is irrigated. Large farms (> 40 ha) are generally specialized in livestock with extensive pasture areas, therefore not irrigated or with a small share of irrigated area.

Table 6 - Farm structural and economic average data by UAA classes

UAA class (ha)	Sample size (n)	UAA (ha)	Irrigated UAA (ha)	Irrigated UAA/total UAA (%)	FNI (€)
<5	55	2.36	1.96	83	34,288
5-15	38	9.50	7.23	76	67,243
15-40	25	26.03	12.80	49	45,332
>40	73	176.04	14.09	8	60,984
Total	**191**	**73.26**	**9.10**	**12**	**52,493**

Source: our elaboration on FADN data (02/09/2020)

The 127 LIC analyzed in the study manage about 60,000 ha of UAA, of which about 17,000 were potentially irrigable. The maintenance and management expenses for irrigation canals totaled approximately 1.4 million € each year. Regional subsidies equaled about 886,000 € annually (Table 7). Values per surface unit were 153.65 €/ha and subsidies were 92.12 €/ha. Based on these unit costs, subsidies estimated in this simulation equated to 60% of the management costs carried by the LIC.

Table 7 - LIC description

Variable	Data
Number	127
Total UAA	59,756 ha
Potentially irrigable UAA	17,101 ha
Eligible expenditure	1,362,680 €
Total contribution	885,742 €

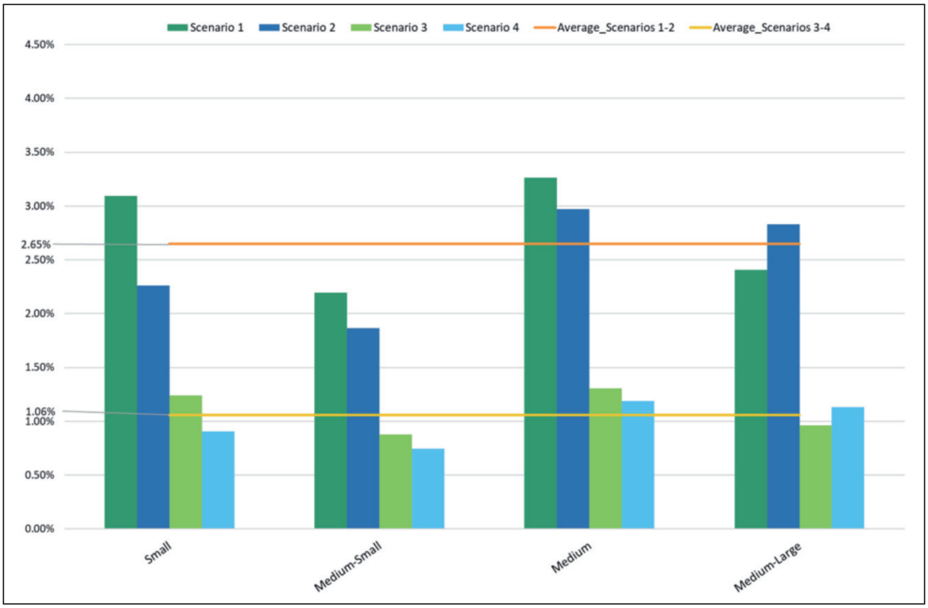
Source: SDI database

3. Results

The average change in the water costs-to-income ratio (both gross and net of subsidies) was estimated for the four scenarios. In Scenario 1 and 2, where the estimate excludes public support, the average ratio of water management costs on net farm income was 2.65%. In Scenario 3 and 4, where costs were discounted for regional subsidies (net of subsidies), the estimated mean ratio was 1.06%.

In order to assess the effects of water cost changes on farms of differing characteristics, the farms in the four scenarios were aggregated by ES, TF, and UAA class and then analyzed. For ES, the highest change in the water costs-to-income ratio was in Medium farms. Their Scenario 1/2 and Scenario 3/4 estimated values were greater than the overall average values (2.65% and 1.06%, respectively). The opposite was true for Medium-Small farms, for which the estimated values for all scenarios were lower than the overall average values (Graph 1). A comparison of the type of water costs assigned to the farms (C_A or C_S), the largest difference was found in Small farms. In the case of Small farms, the Scenario 1 and 3 ratios were above the average value, while Scenario 2 and 4 ratios stayed below.

Graph 1 - Changes in the water costs-to-income ratio in the four scenarios with farms aggregated by ES class

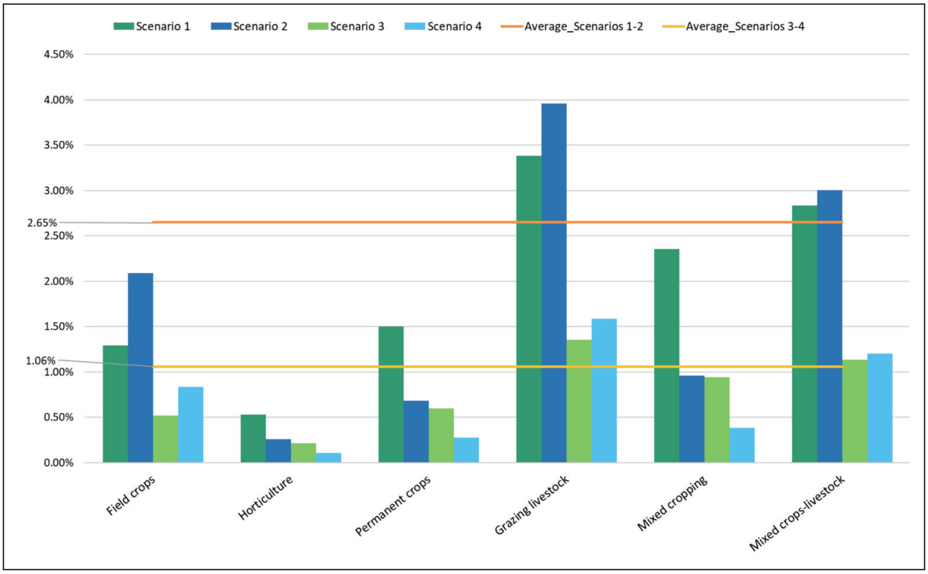


Source: our elaboration on FADN and SDI data.

Analysis of the results by TF were consistent in every scenario. The largest effect on the proportion of farm incomes used to cover water costs was found in farms that specialized in grazing livestock, followed by those with mixed crops and livestock (Graph 2).

A comparison of the type of water costs assigned to the farms (C_A or C_S), the highest difference was found in farms that specialized in permanent crops. Scenario 1 and 3 resulted in higher ratios than did Scenario 2 and 4. For the other TF categories, the values were below the average and differed between the two sets of data. However, the sample sizes for these TF categories were too small to render a statistical evaluation.

Graph 2 - Changes in the water costs-to-income ratio in the four scenarios with farms aggregated by TF

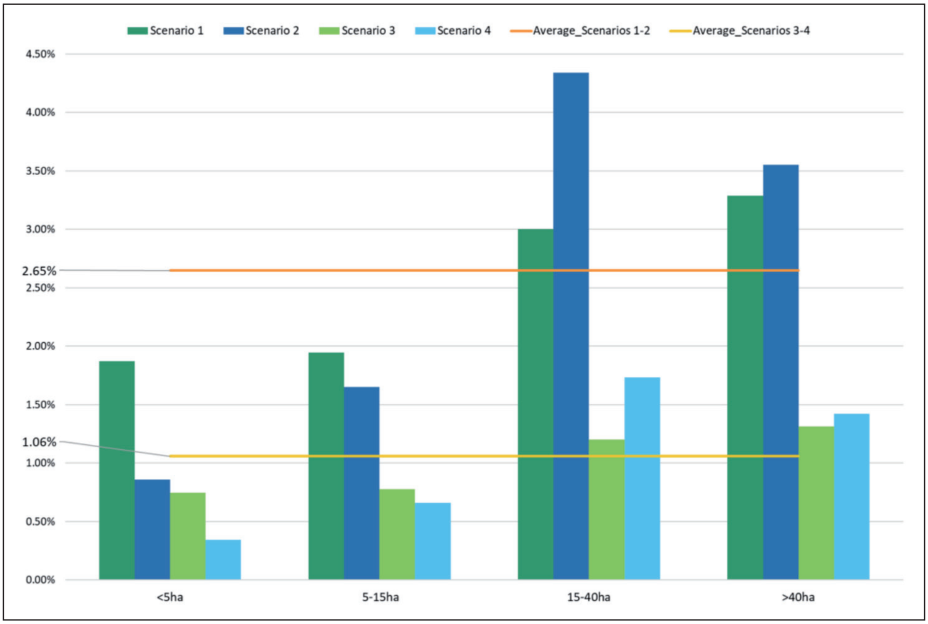


Source: our elaboration on FADN and SDI data.

Aggregating farms by UAA class (Graph 3) demonstrated that the changes in the proportion of operating costs in the larger farms (UAA>40 ha) was higher than the average for all scenarios. Moreover, since the ratio between total and irrigated UAA for these farms was very low (Table 6), the recovery of the costs would have applied to just 8% of the total UAA, on average. In Small farms (UAA<5 ha), the opposite held true. That is, the water costs-to-income ratio was not only lower than the average, but the recovery of the costs would have applied to almost all of the UAA (83%).

In Scenario 1 and 3, the water costs-to-income ratio increased as the UAA increased. On the contrary, Scenario 2 and 4 did not trend linearly. In fact, farms of fewer than 5 ha and farms of 15 to 40 ha produced very different values in the two scenarios: in Scenario 2 the water costs-to-income ratio is of 0.86% and 4.34%, respectively in the two groups of farms, and in Scenario 4 is respectively of 0.34% and 1.74%.

Graph 3 - Changes in the water costs-to-income ratio in the four scenarios with farms aggregated by UAA class



Source: our elaboration on FADN and SDI data.

4. Discussion and conclusions

To date, regional water policy in Valle d'Aosta does not comply with the WFD guideline, since farmers are required to pay only for the management and maintenance service costs borne by the consortia, while environmental and resource costs are waived. Often, even the coverage of the consortia costs is not due because they are partly borne by the regional administration and partly compensated by the work provided by the farmers on a voluntary basis, through the traditional and well-established practice of *corvées*. Specific research should be carried out to estimate the monetary value of farmers' labor devoted to the maintenance of the water network, but also such practices are not sufficient to meet the requirements of the Directive (again, the costs would only be partially recovered).

Based on the currently available data (i.e, the maintenance and service costs borne by the LIC), a scenario where LIC costs were fully borne by farmers was simulated. The consequent changes in the water costs-to-income ratio were modeled under four alternative cost scenarios. Through associating FADN economic and technical data from a significant sample of regional farms with irrigation water cost data extracted from the regional SDI database, a proxy for irrigation water costs was derived and the ratio was estimated. The costs included outlays for management, operation, and ordinary maintenance of land improvement work paid for by the LIC. The approach described provides a novel method on how to integrate FADN data with other administrative data sources as the EU strongly recommends (European Commission, 2020).

Water costs, estimated as a percentage of farm income, averaged 2.65%. In instances in which a portion of the cost is subsidized by the regional administration, then the estimated value falls to 1.06%. Estimations were made under the conservative assumption that all LIC costs were borne by farmers, therefore the share of maintenance and service costs for irrigation is likely to be slightly overestimated. Nevertheless, these values are significant, especially given that in the regional farms the total variable costs (including the cost of casual labor) vary between 25 and 41% of the net farm income, depending on the TFs (Arzeni, 2020). Notwithstanding, based on the WFD guidelines, these ratios are underestimated as they fail to include environmental and resource costs. Hence, it can be assumed that full cost recovery as defined in the Directive might not be economically and socially sustainable. These results seem to confirm the concerns over the affordability of water costs, as farmers may not be able or willing to pay such increase in operating expenses.

Results also showed that the estimates vary when farm data is categorized and aggregated by ES, UAA, and TF class. In general, estimates under different scenarios varied significantly from the average values when farms were aggregated by UAA and TF. Alternatively, ES differences seemed to affect costs less under the different scenarios. In particular, farms larger than 15 ha bore higher irrigation costs (up to 4.34% of farm income). With respect to TF, higher outlays were estimated for grazing livestock farms (up to 3.96%).

The results indicate that extensive farming systems practiced on large farms seem to be most affected by introduction of water pricing policies. For the mountain areas in the Aosta Valley, this is especially important. There, extensive livestock farming is the most widespread and least profitable type of farming; vineyard farming represents a relatively small secondary type of farming. In mountain areas characterized by natural disadvantages, livestock farming is often the only practicable TF that can provide and maintain several ecosystem services, such as biodiversity and water flow regulation, as well as landscape, recreational, and cultural benefits (Herzog *et al.*, 2018; Orlandi *et al.*, 2016; Battaglini *et al.*, 2014). The trade-off between water irrigation for societal and environmental benefits must be carefully weighed against their environmental costs when setting water policy.

High (and underestimated) water costs in extensive TFs and complex estimations in mountain areas raise concerns about WFD implementation in such territories. Indeed, introduction of a water pricing policy in marginal areas, as defined by the Directive, may hasten current traditional farming practice declines and rural depopulation with negative effects on the economic vitality of local communities and on social and environmental benefits related to irrigation.

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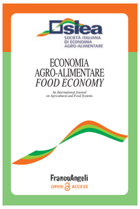
Economia agro-alimentare / Food Economy

An International Journal on Agricultural and Food Systems

Vol. 23, Iss. 3, Art. 9, pp. 1-16 - ISSN 1126-1668 - ISSNe 1972-4802
DOI: 10.3280/ecag3-oa12760



Mapping data granularity: The case of FADN

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Abstract

The present analysis looks into the issue of mapping information contained in the FADN database aimed at finding a methodology useful as a preliminary analysis to data extraction. To the purpose the concept of data granularity has been introduced. The method has been used to perform a farm-based analysis, revealing a wide heterogeneity of factors and levels that show the existence of specific data 'patches'. The work proved to be able to increase awareness regarding effective data availability as a preliminary analysis to queries performed on relational data-bases which are not designed from a systems basis, and that can be considered valid for any survey-supplied data.

Article info

Type:
Article
Submitted:
14/05/2021
Accepted:
21/09/2021
Available online:
12/01/2022

JEL codes:
C18, C81, Q12

Keywords:
FADN
Farms
Survey
Granularity
Big data

Managing Editor:
Lucia Briamonte,
Luca Cesaro,
Alfonso Scardera

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Introduction

Understanding and monitoring the agricultural sector, exploring farm structure and dynamics is a fundamental task of every country, and one of the most powerful tools developed from the EU is represented by the Farm Accountancy Data Network (FADN). It is a sample survey conducted every year by EU Member States on the basis of a common regulation and a harmonized methodology. Every EU country developed and is currently managing its own FADN – compliant database, whose standard is defined in the 'form and shape of farm return' (EU, 2015). Therefore, the FADN database includes a common dataset of mandatory fields but it also provides information that can be different in each country, including several orders of information, e.g. dealing with agrotechnology, market and sustainability.

The FADN database represents an important source both for policy makers and for researchers, indeed it has been already used e.g. for decision making, to assess CAP, to estimate farm efficiency, and compare production activities. However, the number of field descriptors, and observed values is making FADN a complex database (Hand, 2020), with consequences on the performances of any models making direct or indirect use of collected data.

The quality of a dataset is given by several aspects including Accuracy and Precision, Legitimacy and Validity, Reliability and Consistency, Timeliness and Relevance, Completeness and Comprehensiveness, Availability and Accessibility, Granularity and Uniqueness (see e.g. Harrington, 2016).

Most of these qualities can be measured by statistically-based metrics (Karr, 2006), also when having to do with heterogeneous data (Micic, 2017); however, such approaches are hardly useful to detect the level of detail of available data.

Data availability is at the base of statistical approaches adopted to derive indicators and technical parameters. However, the number of factors and levels available to compute such values depend on each other.

To the scope the concept of granularity has been explored here, meant as the number of factors and levels that determine the degree of aggregation to be used to produce statistically significant values.

To the purpose at first, we will have a glance at the FADN dataset and describe the methodological approach adopted, then we will describe the distribution of granularity and its effects on two case studies. Finally, we will draw the final conclusions.

2. Materials and methods

The FADN database

The FADN survey is carried out in each Member State by a liaison agency which in Italy is represented by CREA (Council for Research in Agriculture and Agricultural Economics analysis, research centre supervised by the Ministry of Agricultural, Food and Forest Policies). The survey, performed through a network of data collectors (experts of the agricultural sectors), is performed on a sample of agricultural holdings with an economic size of commercial (equal or more than 8,000 euro), which are selected on the basis of sampling plans established at the level of each Member State and according to guidelines provided by the European Commission. The sampling plan ensures the representativeness of the returning holdings as a whole and defines the number of farms to be selected by region, type of farming (ToF) and economic size classes, expressed in terms of standard output (SO), and also specifies the rules applied for selecting the holdings. The random sampling allows the extension of the results of the farms in the sample to the universe of the farms as a whole that is formed by the subset of the EU universe.

The information collected draw a portrait of farm's structure, their financial and economic aspects, environment, social issues, labour machinery etc. In particular, in the database it is possible to find general information related to farms (as Utilized Agricultural Area (UAA), economic size as standard output (SO), working units, kind of property, legal form, Gross production etc.). Other information is related to financial and economic aspects (as derived from accountancy as costs, investments, debts, value added, assets and liabilities, subsidies). In the FADN database it is also available some information related to social aspects (level of education, age of farmers, gender, labour etc.). Other information are linked to statistical aspects (information on sample and weights), environmental aspects (use of fertilizers and pesticides, use of water), and detailed information about land use (hectares of area dedicated to each cultivation) and livestock (number of heads of animal per species and categories). Some of the variables in the database are continuous (surfaces, number of heads, working hours, KW, subsidies received, etc.) others could be categorized in different classes (classes of UAA, classes of SO) or modalities (as altimetry: mountain, hill, plain) while others could be dichotomous (yes/no). Additional tables have been recently introduced in order to simplify specific research. The list of most relevant tables and a synthesis of their contents is given in Annex 1. A description of meta-data is reported in FADN documentation (RICA, 2021).

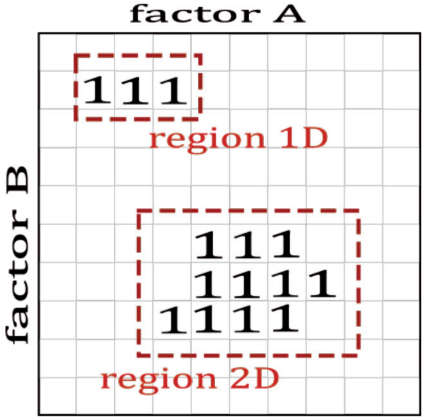
The FADN database is mainatined as a relational SQL-DB by the applicative GAIA that helps validation, gap filling and imputation. Tables could be linked directly (1-1) or after some elaborations (1-N) and they have a high level of redundancy allowing a prompt readability and giving the user the possibility to manage them independently – moreover codes accompanying descriptors increase their robustness.

A definition of granularity

Granularity, commonly referred to space or time data resolution, can also be referred to more general and abstract features. Each conventional Data-Base collects two kinds of information, alphanumeric/descriptive/categorical and numerical ones. Though every field can be used to extract records, categorical and numerical-discrete can be used to classify values, allowing each variable to be hosted by a (sparse) N-dimensional matrix (N being the number of factors).

Figure 1 display the case of a sparse 2D matrix representing the availability of data on 2 factors survey, where it is possible to identify the localised availability of data on levels 2,3,4 of factor A for some samples, and availability of several combinations of levels of factors A and B in another region, meaning that in the first region the matrix has a 1-dimension character, whereas it has a 2-dimensional character in the second one.

Figure 1 - Example of a sparse matrix representing data availability for 2 factors of 10 levels each



In terms of data collected from surveys (as FADN), each categorical data determines a dimension, and records may be split on the base of each of them over and over, till the sample size becomes too small (or empty) to compute reliable statistics for a given variable, or there are no levels to be compared as level are not equally populated – e.g. in FADN, farm managers are mainly males. Also, things could be different for each variable – information on farm activities (cropping/livestock) depends on farm specialisation. Granularity of each variable is described by the distribution of factors (local dimension of data matrix), levels (identifying the region of the matrix rich of data) and sample size characterizing the context of interest.

The analysis of granularity aims at producing a map of data availability which is preliminary to any statistical analysis including dimension-reduction (as Principal Component Analysis, Factor Analysis, discriminant analysis, etc..), aimed at describing a data-set which has not been designed on the base of a systemic view/model.

Exploring granularity distribution is a matter of combinatorics. As an example, if factors are *a,b,c,* possible combinations are represented by: *a, a-b, a-b-c, a-c, b, b-c, c*. In general, possible combinations of *k* factors can be obtained by: $\sum_{k=1}^{n}\binom{n}{k}$. Being factor levels given by (n_a, n_b, …), the number of possible levels for each combination is: $NL = \prod n_a \cdot n_b \cdot \ldots$ - namely, if $n_a=3$, $n_b=4$, $n_b=5$, the potential number of levels for combination *a-b-c* is $n_a \cdot n_b \cdot n_c = 60$. For more factors and levels combinations increase considerably generating a three graph whose exploration represents a well-known computational problem.

As the splitting is carried on, the sample size does not allow statistical analysis: e.g. organic farms are far less numerous than conventional ones and as increasing the number of factors, splitting make the size organic sample too small. As the majority of analyses performed on FADN are aimed at comparing variables related to different levels, a minimal size is required – in the following analysis a minimum sample size (*NMIN*) of 5 has been adopted.

In this study we focus the attention only on data collected on farm tables. Each farm has a maximum of 158 numerical variables, coming from 5 tables (FARMS, ENVIRONMENT, LAND-USE, BUDGET-CE and BUDGET-SP) some of them representing intensive values (indicators), while other are farm-wide (e.g. total surface, income, labour, or livestock units).

Tables include 13 non-redundant categorical data (factors), which are listed in table 1 together with the number of their levels. Four of them are dichotomous (yes/no) while others describe the same character with a different detail, - REGION (21) & AREA (5), ALTITUDE_3 (3) &

ALTITUDE_5 (5), TOF_4 (61) & TOF_2 (9). For the remainder of the study only the first one of each listed couple will be used. In table 1 they have been identified with a code, which are used in discussion below.

Table 1 - Factors of farm-based tables and their modalities

Code	Field	Description	Classes or modalities
A	REGION	Administrative Region or autonomous province (NUTS2 territorial units)	19 administrative regions and 2 autonomous provinces of Trento and Bolzano
	AREA	Grouping of Regions	North-West, North-East, Center, South, Islands
B	ALTITUDE_3	Identification code of the altimetric area a three types	Mountain, Hill, Plain
	ALTITUDE_5	Identification code of the altimetric area a five types	Internal mountain, coastal mountain, internal hill, coastal hill, plain
C	LFA	Less favoured area	Municipal territory not disadvantaged; Partially mountainous and partially disadvantaged municipal area; Totally mountainous and totally disadvantaged municipal area; Municipal territory with total or partial disadvantage due to depopulation; Municipal territory with specific disadvantages, partially or totally
D	TOF_4	Type of farming (61 levels)	Detailed levels of activities as defined in EU regulation 220/2015
	TOF_2	Type of farming (9 levels)	Specialist field crops; Specialist horticulture; Specialist permanent crops; Specialist grazing livestock; Specialist granivores; Mixed cropping; Mixed livestock; Mixed crops – livestock; Not classified
E	MANAGEMENT	Type of farm management	Direct with family members only; Direct with a prevalence of family members; Direct with a prevalence of extra-family; With wage earners; With only subcontracting; Other forms of management

Table 1 - Continued

Code	Field	Description	Classes or modalities
F	LEGAL_FORM	Farm legal form	Individual holding; Simple company; Company at collective name; Joint stock company (S.p.a.); Cooperatives (limited or unlimited liability); Other typology; Limited partnership (S.a.s.); Limited Liability Company (S.r.l.); Limited partnership by shares (S.a.p.a.); - Social cooperative; Other recognized and unrecognized association; Public authority
G	GENDER	Gender of farmer	Male/Female
H	SETTLEMENT	Method of settlement of the entrepreneur	Direct with family members only; Direct with a prevalence of family members; Direct with a prevalence of extra-family; With wage earners; With only subcontracting; Other forms of management
I	YOUNG	Presence of Young entrepreneur	Y = the entrepreneur is less or equal to 40 years old; N = over 40 years old
J	DIVERSIFIED	Presence of farms diversification activities	Y/N
K	ORGANIC	Presence of Organic farming	Y=organic; N=conventional
L	CLASS_UAA	Class of Utilized Agricultural Area	Less than 5 ha; 5 - 15 ha; 15 - 40 ha; more than 40 ha
M	CLASS_PS	Class of Standard Output (€)	4.000-8.000; 8.000-15.000; 15.000-25.000; 25.000-50.000; 50.000-100.000; 100.000-250.000; 250.000-500.000; 500.000-750.000; 750.000-1.000.000; 1.000.000-1.500.000; 1.500.000-3.000.000; more than 3.000.000 €

3. Results

The factors (*NF=13*) result in a number of possible combinations *NC = 8191* and to a potential number of levels *NL=16'114'775'040*.

To explore the combinations a recursive code has been developed in R, which has been run on FADN 2015 data-set. Because of the large number of combinations, a stopping rule has been included on the base of subsample size (*NSTOP*).

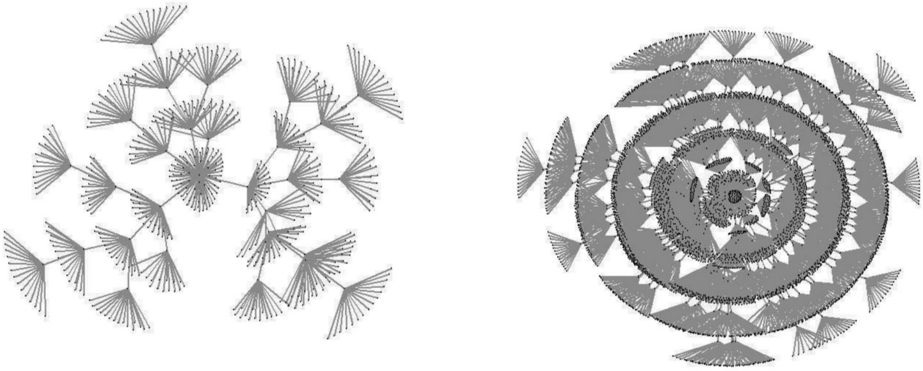
The computing time has been estimated as *t = 10 (a - b log10 NSTOP)* (with *a=7.47, b=1.81, R=0.999* on a core *i7* at *1.80GHz*).

The distribution of granularity, that is the combination of factors/levels/sample size is written into a table including the possible factorial analysis that can be performed on FADN for FARM-based records with the selected sample size.

As each combination is deriving from a simpler one, the process of exploration of combination can be represented as a tree graphs that can be used to show a combination of factor levels that can be progressively added to a factorial analysis.

Figure 2 shows the graphs obtained with *NSTOP=5000 (572 edges, left side)*, and *NSTOP=2000 (4556 edges, right side).*

Figure 2 - Plots of tree graph[1] *derived for a threshold of 5000 records (left) and 2000 (right)*



As the threshold (*NSTOP*) decreases the graphs become more and more complex and hardly readable, however it can be easily seen that with *NSTOP=5000* a maximum of *5* factors can be explored, and with *NSTOP=2000*, 7 factors. Also, most of the branches are very selective - for each factor, few levels are selected for more complex combinations of factors.

1. Tree graphs have been generated by *igraph* (Csardi, 2006) and *ggraph* (Pedersen, 2021) R libraries.

Case studies

To make the method fully understandable, a closer look to the technique is given, starting from a table obtained for *NSTOP=50*, resulting in *513'795* combinations of factors/levels, that required a computation time of *6.9 hrs*.

1. Organic farms - In the last decades, interest in sustainable crop management has grown considerably, and analysing the differences between organic and conventional farming is an issue of considerable interest. However organic farm samples in FADN are not as rich as required for a thorough analysis. From the list of combinations obtained setting *NSTOP=50*, only *8'847* (*1.7%* of total) allow to have an adequate number of farms with both levels of ORGANIC (y/n) in the same context (combination of factors) - some of those combination, together with their numerosity, are reported in Table 2. Sample size shows that organic farms are far less than conventional (about *1/20*) on a national basis, however an analysis can be performed on almost every REGION (not A [2]). Also, for each region analysis can be performed just on some ALTITUDE (B) - for region A [1] only level B [1] (plain) is adequately populated. The same happen crossing regions with LFA (level C [2]), and few with TOF (D [2,9]), or MANAGEMENT (E [5]). Looking at the possibility to analyse the effect of ALTITUDE (B), not splitting the sample over the regions, samples are adequately large to analyse the combination with almost every LFA (C[2-6], and we can do the same combining YOUNG and DIVERSIFIED - in this case as both factors are dichotomous (y/n) splitting is reduced and the analysis includes all levels. As the combination includes more and more factors the levels included decrease and comparison can be done only for a few combinations of levels.

Table 2 - Excerpt from granularity table with records allowing to compare organic and conventional farms. The first column reports combination of factor & level, the right ones sample sizes of the two levels of factor ORGANIC (y/n)

Combination of factor[level]	**Organic**	**Conventional**
K	465	8582
vs regions		
A[1]-K	23	515
A[3]-K	19	356
…		
vs regios & other factors		
A[1]-B[1]-K	19	379
A[1]-C[2]-K	13	281

Table 2 - Continued

Combination of factor[level]	Organic	Conventional
A[1]-D[2]-K	7	57
A[1]-D[9]-K	9	177
A[1]-E[5]-K	13	170
…		
vs altitude & LFA		
B[1]-C[2]-K	96	1706
B[1]-C[3]-K	31	402
B[1]-C[4]-K	33	480
B[1]-C[5]-K	98	1234
…		
vs young & diversified		
I[1]-J[1]-K	316	6683
I[1]-J[2]-K	59	793
I[2]-J[1]-K	75	944
I[2]-J[2]-K	15	162
…		
vs region, altitude & LFA		
A[1]-B[1]-C[2]-K	13	281
…		
vs more factors		
A[14]-B[3]-C[2]-D[9]-F[5]-G[2]-I[1]-J[1]-K	8	60

2. Farm Income - Economic sustainability is the foremost important aspect for a farmer, and FADN is expected to be a source of important information to develop market analysis and economical performances of different sub-sectors. An interesting analysis could be aimed at detecting which aspects CLASS_PS (M, see table 1) may be related to. To the scope from the whole set, combinations are selected with at least two levels of CLASS_PS for the same combination (context). The selection includes 13% (66'584) of total combinations. While 1/4 (15'620 combinations) involving REGIONS (A, all levels), 1/2 (30'068 combinations) ALTITUDE (B), 1/2 (28'672 combinations) LFA (C[2-6]), 1/4 (25512 combinations) TOF (D[2-3,5,8-9]), 1/2 (27'770 combinations) MANAGEMENT (E), 1/2 (29'583 combinations) LEGAL FORM ([5,7,12]), 1/2 (31'075 combinations) GENDER (G), 1/2 (27'876 combinations) SETTLEMENT (H), 1/2 (30'721 combinations) YOUNG (I), 1/2 (29'720) DIVERSIFIED (J), 1/2 (24'012 combinations) ORGANIC (K), and 5/8 (36'219 combinations) UAA (L). However not every level is equally represented. If the 4 levels of L are comparably populated in terms of combinations (6732, 7430, 9369, 12688), for ORGANIC, 23'343 combinations are related to conventional farms and only 668 combinations are related to organic ones. Of the latter ones only 147 combinations include the UAA (L [2-4]) - on the other hand conventional farms can be combined with every UAA combination (2835, 3105, 3894, 5081).

The whole sample (9'024 farms) can be used for a general study though it appears that 7 to 11 PS levels are covered out of the 16 possible - the first 3 rows reported in table 3 show the regions with different PS class coverage. As combinations become more complex, the modalities available may decrease, as can be seen in the 4th row of table 3, or maintain its range, as in one of most complex combinations reported in 5th row.

Table 3 - Excerpt from granularity table with records allowing to compare farms with a different class of Standard Product. The first column reports combination of factor & level, the second the corresponding sample size for the available levels (minimum 2) of factor CLASS_PS

Combination of factor[level]	**CLASS_PS**															
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**
A [1]	–	–	–	47	78	147	119	96	34	11	–	–	–	–	–	–
…																
A [6]	–	–	–	123	15	116	12	94	54	54	19	24	8	–	–	–
…																
A [13]	–	–	14	44	65	19	131	128	48	23	7	6	6	–	–	–
…																
A [1] -B [1] – C [2]	–	–	–	27	53	95	59	36	14	–	–	–	–	–	–	–
…																
D [9] -E [5] -F [5] -G [2] -H [7] -I [1] -J [1] – K [1]-L[4]	–	–	7	22	12	33	6	33	5	21	11	8	15	–	–	–

4. Conclusions

In the research, not every data-set is designed with a system view point and with a model in mind, and observed variables and factors are identified by different criteria, including economical aspects. Nonetheless such databases, including the FADN, collect a large amount of information, allows to obtain indicators and technical coefficients of relevant importance. However, such values cannot be obtained for every context (e.g., crop or livestock data are only recorded in specific farm types, or some regions).

The presented methodology is aimed at defining a technique for a preliminary exploration of data-sets based on identification of regions of data with a potentially higher density of information, challenging the issue of mapping information contained in the FADN database as a preliminary step for further investigations. Several orders of problems have been faced - together with the factorial & combinatorial aspects.

The method used to perform a farm-based analysis put in evidence a large heterogeneity of factors and levels that witnesses the existence of specific data 'patches' or clusters - in terms of granularity it means that a fine-grained texture characterizes only specific combinations of factors/levels.

The work proved to be able to increase the awareness about effective data availability as a preliminary analysis to queries performed on a relational database as FADN, which can be considered valid for any survey-supplied data.

The approach is expected to be useful to FADN management boards, to increase homogeneity of data granularity by optimising farm sampling or rearranging survey entries (in respect of FADN rules).

Further on, the way to display results has been challenged to make the analysis and result readily comprehensible. The possible combinations of records rich enough of information to enable statistical analysis is so huge to make static tree diagrams only useful to have a glance at granularity distribution and complexity, not to a direct browsing of information.

Future directions include the possibility to use interactive visualization tools to navigate combinatorial graphs.

Annex 1 - List of most relevant tables in FADN database

- FARMS reports for each holding information on location at several levels of space granularity, organization, management, profile, economic aspects, resources availability and usage. FARMS is considered the main table - its records could be matched directly (1-1) with some other tables such as ENVIRONMENT, SAMPLE, BUDGET-CE, BUDGET-SP and indirectly (1-N) with every other table.
- ENVIRONMENT collects information useful to understand farm environmental conditions, including altitude, slope, soil texture, water availability and type of irrigation. Latitude and Longitude has been considered for a range of years but definitely removed (in 2017) because of the spatial resolution of FADN (Lat/Lon only referred to farm administrative address). Other databases, (e.g. the one managed by AGEA, linked to satellite imagery and aircraft survey), are expected to supply a parcel-level land-use detail.
- SAMPLE collects information related to the representativeness of selected farms on the land-use. FADN adopts the principle that farms should be sampled with the aim of representing a country level universe. Such strategy allows to obtaining an integrated survey structured unit able to increase considerably record reliability, and allowed, from 2003, to give to each farm a weight estimating its representativeness on a national and regional[2] basis, which is obtained from three variables: region, economic size (since 2010 expressed in Euro) and type of farming, following the Neyman methodology [23]. Each year-farm entry, coded by a series of identifiers, reports weight (from universe and sample size) allowing to scale up each farm data to get an estimate of its territorial relevance.
- CERTIFICATION table records information on type of certification and its object (the farm or a given surface) e.g. denomination of origin or geographical indication.
- SUBSIDIES table collects information detailed by type of subsidy, type of policy, duration, amount[3].
- BUDGET_CE collects most terms (63) of farm accountancy with different aggregation criteria (see Figure 1).
- LABOUR COSTS table collects details on costs related to different kinds of labourers (e.g. external, family) as number of people, working days, salary.
- BUDGET_SP collects most of terms (44) estimating farm capital.
- BUILDINGS collects information about estates by building typology and ownership, including number of buildings, size, age and value.
- MACHINERY collects information about machinery power by type of machine and ownership, including power, age, and value.
- LAND-USE reports the surface utilized of main surface types of cultivations (arable, permanent crops, pasture, horticulture, woody crops, woodland, tares – woodland and woody crop surfaces are usually not included in cropland).

2. Hereafter "regions" are NUTS2 territorial units
3. In CERTIFICATION and SUBSIDIES, objects may be represented by the whole farm or the specific activity.

- SURFACES collects data on each farm surface – for each cadastral quality and slope class, collects the number of fields, their altitude, total surface (detailed ownership, irrigated) and estimated value. Data however do not indicate spatially explicit land-use patterns due to the non-spatial nature of FADN requirements.
- PLANTS collects economical detail on permanent crops by variety and training system.
- CROPS include both economical (detail of costs and income) and agrotechnological information by species, cropping system including use of resources. About measure units, the EU suggests using quintals and hectares when possible.
- WATER-USE collects information by species and cropping system of irrigation details (days, avg daily hours, water usage and if combined to fertiliser).
- FERTILIZERS collects information by species and cropping system and typology of product together with distributed amount and N, K and P content.
- PESTICIDES collects information by species and cropping system and typology of product, indicating measure unit, position, class of toxicity of: unit price, distributed amount, distributed value, crop surface.
- LIVESTOCK collects information by livestock typology, attitude, and technical information (Head Units, milk units, milk production) and economic data (e.g. SGP, TGP, GPS, FRP, …).
- ANIMALS reports information by animal species and category, management, reporting prevalent attitude of: number of heads, weight, age, lifespan, value.
- PRODUCTS records for each product, type of warehouse, cropping system, identifying measure units: production, together with initial and final inventories, acknowledged, sold and transformed amounts and values.
- SERVICES reports for every activity, offered service, use of renewable energies: size, annual capacity (e.g. customers).
- LABOURERS collects for every worker (personal information is omitted) by type of job, specialization, country of origin, and sector of activity: number of males and females, hours, hours machine, working days and third party.
- PERSONNEL add registry information including gender, family member or relative, management role, level of study, professionalisation, external job, external income, year of birth, year of enrolment.

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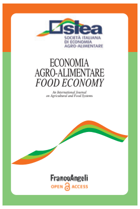
Economia agro-alimentare /
Food Economy

An International Journal on Agricultural and Food Systems

Vol. 23, Iss. 3, Art. 10, pp. 1-21 - ISSN 1126-1668 - ISSNe 1972-4802
DOI: 10.3280/ecag3-oa12770



Use and users of FADN data in Italy

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Abstract

The Farm Accountancy Data Network (FADN) is a sample survey that annually gathers information from more than 80,000 European farms. Its main aim is to provide data to the EU Commission used in the assessment of farm profitability and in the evaluation of Common Agricultural Policy (CAP) impacts. FADN results are also used and published nationally in almost all the Member States. The Italian FADN (named RICA - Rete Italiana di Contabilità Agricola) provides data for stakeholders and researchers, serving as an important source of information for specific analysis and meeting a wide range of policy needs. Data are stored in an online database, available for institutional users under an agreement or a formal accession request. For non-institutional users, a public Datawarehouse supplies/ provides selected information already aggregated by farm type, economic size, and region. Like other surveys, FADN can be considered as a public good, whose general benefit and utility depends also on its impact on users. One way to evaluate these benefits is the identification of users, the data used and their level of satisfaction. This monitoring activity is not performed in the Italian FADN: users and usage are not always tracked and the information about their satisfaction is lacking. The paper investigates this aspect (which has been called "inherent data dissemination" for the first time, focusing on the extent and ways in which FADN is made available: the most important area of analysis covered by the data. Two instruments are

Article info

Type:
Article
Submitted:
28/04/2021
Accepted:
20/09/2021
Available online:
12/01/2022

JEL codes:
M41, Y1

Keywords:
FADN
RICA
Informative needs
Users' analysis

Managing Editor:
Lucia Briamonte,
Luca Cesaro,
Alfonso Scardera

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examined: the FADN database online (BDR) and the request forms submitted to CREA to ask for customized tables based on a set of selected variables. The first tool has been analyzed by submitting a questionnaire to the list of users, while for the request forms, all the submissions processed during the period 2011-2020 have been examined.

Introduction

The Farm Accountancy Data Network (FADN) is a sample survey that annually gathers information from more than 80,000 European farms representing around 90% of production. European Union (EU) is responsible for the regulatory framework in which FADN operates as well as for funding it with public money. The overall public cost of FADN in EU-28 was identified as some 59 million euros per year (Hill and Bradley, 2016). Information is collected according to a questionnaire (Farm Return) and following legal requirements specified in the EU Regulation 1217/2009, supplemented by implementing legislation. FADN is one of the most important agricultural surveys deployed in European Union: it is the only source of microeconomic data, based on harmonized bookkeeping principles, and gathers structural and economic information of agricultural holdings (stratified by region, economic size and type of farming), comparable in space and time. The first aim of this survey is to provide data to the EU Commission for the assessment of farm profitability and the evaluation of the Common Agricultural Policy (CAP) impacts. The enlargement to new Member States, the increasing supply of data and wider informative needs have made FADN worthwhile for purposes that go beyond those contemplated at the beginning. There are four main methods by which the results of FADN are communicated by the Commission (Hill *et al.*, 2016): (i) Standard Results, periodically produced and published to describe in detail the economic situation of farmers by different groups; (ii) FADN public database; (iii) specific works and publications (by Member States or type of farming, reports on income evolution, ad hoc analysis regarding CAP evaluations, etc.); (iv) contributions to research projects (as 7th Framework Programme, Horizon2020, etc.) or specific evaluation (policy impact, policy prospective, economic studies, models, climate change, etc.).

FADN is used not only by the Commission but also by Member States governments and other policy analysts for research purposes. The Italian FADN (named RICA - *Rete Italiana di Contabilità Agricola*) provides data to the EU Commission (mandatory by regulation) but also for a broad category of stakeholders (public institutions, Universities, public and private research, individual researchers), serving as an important source of data for the national research system and meeting a wide range of informative needs. FADN dataset is produced, managed, and disseminated by the Policy and Bioeconomy Unit of the Council for Agricultural Research and Economics (CREA, the FADN Liaison Agency between Italy and the European Commission). Raw data are stored by CREA and most part of the information is made available in an online database (BDR – *Banca Dati RICA*). Ensuring research data are easily accessible, so that they can be used as often and as a widely as possible, is a matter of sound stewardship of public resources (Arzberger *et al.*, 2004). Being a publicly funded survey, both data and research itself have strong public good characteristics (Kaul *et al.*, 1999) and should be openly available to the maximum extent possible (unless restrictions because protection of confidentiality and privacy). An open and shared public data system increases the opportunity to raise the quality and productivity of research, avoiding the certain lost opportunity cost, difficult to measure (Ulhir and Schröeder, 2007). Moreover, it is more frequently subject to a process of validation and verification coming from the users and this process increase the quality of data and research outcomes.

All the stages of the Italian FADN data production and supply chain is supported by a technical infrastructure which ensure as far as a possible an efficient data management. Being a completely digitalized dataset, it can be shared easily in an extensive way. In terms of access, the Italian FADN can be considered as an open resource, organized in different levels, each with different details, data aggregation and complexity. Users can have a direct access to the online database or obtain FADN data through the submission of a request form limited to a set of variables. For non-institutional users and the general public, a Datawarehouse displays a set of selected information already aggregated by farm typology, economic size and region. In addition, farmers can have a private access to their own FADN data by mean of a specific tool (*Cruscotto aziendale*) available on the web (through an individual password).

The scientific and socioeconomic benefits of a greater openness in the context of public research is not easy to assess because the already mentioned public nature of FADN as a good. Benefits and values related to statistics can be measured considering (i) objective indicators (number of downloads, citations in the media, etc.), (ii) subjective indicators from users' satisfaction survey, (iii) estimation of monetary value (UNECE, 2018). Counterfactual analysis is not easy: judging how less good policy decisions would be in absence of the information provided by the dataset is one such difficulty. In case of FADN, it is instead easier to assess the private benefits for the farmers of having access to FADN results: they may, for example, improve their profits benchmarking their own performance (Hill *et al.*, 2016).

Following the indication of the Task Force on the Value of Official Statistics, established in 2015 by the Conference of European Statisticians bureau and composed of experts from national and international statistical organizations (UNECE, 2018), one way to detect and measure the presence of benefits is through the identification of users' characteristics, data uses and level of satisfaction. This scheme has been followed in an inquiry realized in Italy by the National Institute of Statistics (ISTAT, 2019). The "User Satisfaction" survey is related to the statistical products/services disseminated on the official website. Users are invited to full a form once they access on the website (on a voluntary basis). The investigation gathers information about the informative needs of citizens and institutions, their level of satisfaction, the frequency, and their general profile.

A similar methodology has been applied to monitor for the first time users and uses of Italian FADN. The work is focused on the extent and way in which Italian FADN data are made available and used. Two different level of access are examined: the FADN database online (BDR) and the request forms submitted to CREA by which users ask a set of selected variables, indicating the scope and the area of interest. BDR users have been analyzed submitting a questionnaire by email to all the recorded accounts having access to the platform: aspects like the final use, the level of satisfaction, the clearness and reliability of FADN database have been investigated. Regarding the request form, all the forms submitted during the period 2011-2020 have been examined.

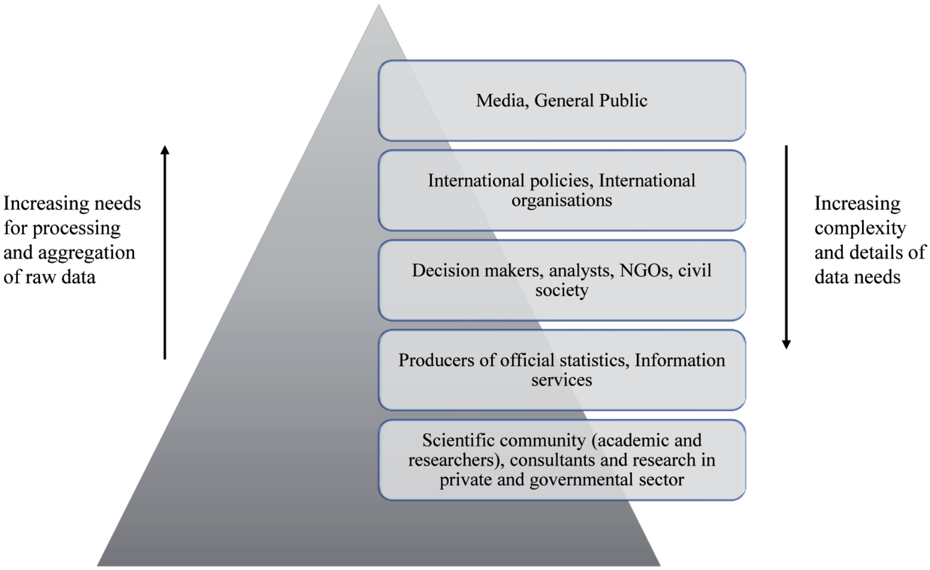
1. Background

The general structure of Italian FADN can be considered as a combination of data, procedures, resources, and people managing the production, elaboration, and dissemination of information regarding the structural and economic condition of Italian agricultural holdings. This is supported by an information technology (IT) system having an important role in the collection, management, control, transition, and analysis of the primary data directly gathered from the farm and stored in a digital database, processed, and made easily available for the users. The system is set up to fulfill EU requirements (being a mandatory survey for the Member States) but also to satisfy the information needs expressed by several categories of stakeholders (institutions, researchers, etc.).

The whole process is not linear but includes a series of dynamic "chain link" feedbacks characterizing the data trajectory from the data collection to the dissemination: data sharing options are one of the main elements of this trajectory (Ulhir and Schröeder, 2007) and one of the most important factors characterizing the efficiency of this kind of public good. In economic theory, public goods are formally defined as goods characterized by non-rivalry of consumption (the consumption of one individual does not detract from that of another) and non-excludability (it is difficult if not impossible to exclude one individual from enjoying the goods) (Samuelson, 1954; Stiglitz, 1999). Italian FADN is funded by public money, the information is shared at the lowest possible cost (the marginal cost of dissemination is essentially zero) and with high scientific and socioeconomic benefits. The benefits of this kind of open access data systems are widely recognized (Verschragen and Schiltz, 2007; Ulhir and Schröeder, 2007; Arzenberg *et al.*, 2007). They (i) reinforce scientific inquiry, diversity of analysis and new research, (ii) support studies on data collection method and measurement, (iii) develop different methods of analysis, (iv) enables the exploration of new topics, intersectoral and international research, (v) facilitate the education of new researchers. Moreover, they help to maximize the research potential of the digital technologies and networks, providing greater returns for the public investment in research (Fienberg *et al.*, 1985; National Research Council, 1999).

Measuring the efficiency and benefits arising from the use of FADN is not easy: the nature of FADN as a public good complicates the assessment of worth and is difficult to determine what might have been possible if the data were not open or available. However, an evaluation can be made through specific users' satisfaction surveys. The dissemination strategy of Italian FADN is based on a segmentation of users and the access and details of information is structured according to their different needs. The importance of identifying a list of users' categories has been recognized by the European Statistical Advisory Committee (ESAC) as a basis to create a strong communication strategy. ESAC classifies users into institutional users (such as international organizations, agreements, etc.) and non-institutional users (further divided according to their interest in statistics). The same concept is the core of another classification proposed by the Task Force on the Value of Official Statistics (Figure 1) that identifies (i) users with a general interests (citizens, media and journalists, students and teachers); (ii) users with a pre-defined/structured interest as in the international policies and monitoring frameworks or international organizations; (iii) users with a specific subjects/domain of interest (decision makers, policy makers, marketing analysist, experts in a specific field, private business and NGOs organizations); (iv) users with a reuse and reproduction interest and producers of official statistics; (v) users with a research interest (research centers, scientific community, academic and researchers, etc.) (UNECE, 2018).

Figure 1 - Users and users' needs



Source: UNECE (2018).

The information collected in the Italian FADN is selected, displayed, and supplied as an open data system but according with different categories of users. As mentioned, CREA is the Liaison Agency between Italy and European Commission and is the responsible of the data collection at national level. Like other Member States (Cyprus, Croatia, Estonia, Finland, Germany, Ireland, Latvia, Lithuania, Netherland, Poland, Czech Republic, Slovakia, and Hungary), the organizational setting of FADN relies on a public research institute. As public body, one mission is to promote the public research activity removing any barriers in the use of data, disseminating the results, supporting policy analysis and the whole national research system.

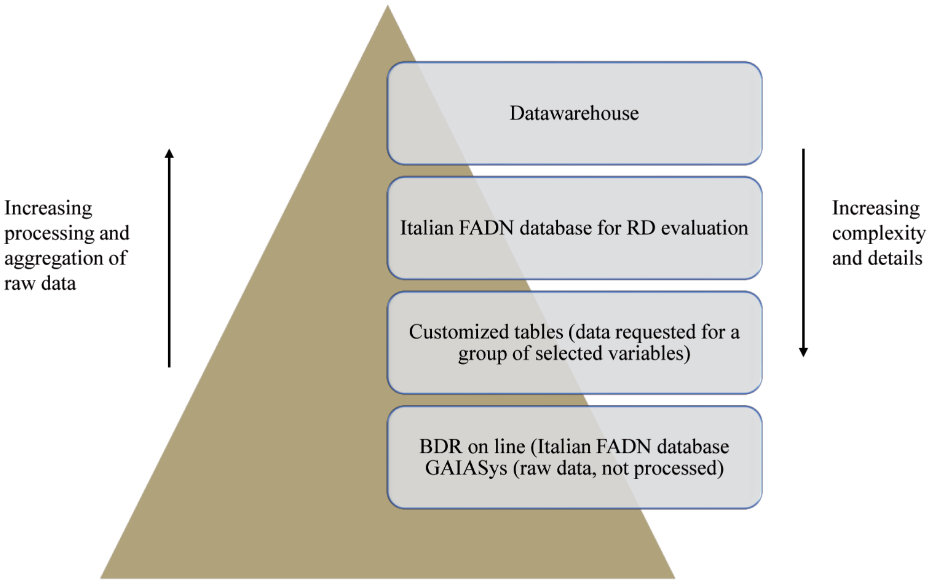
As anticipated, FADN data in Italy are available with different level of access and detail, in compliance with the principle of statistical secrecy and protection of personal data (Figure 2):

- GAIAsys: is the raw FADN dataset of primary data. It contains all the information gathered directly from the farm: data are not processed or aggregated. GAIAsys is used for research purposes when a high detail is required (for instance, when is necessary to separate costs for gasoline, diesel, methane, etc., otherwise aggregated in one item as energy cost).

- FADN Database online: one important process in the Italian FADN is the transformation of raw data in information available for the users. This is realized through the Database online (BDR[1], *Banca Dati RICA*) where information can be downloaded as data or elaborated as reports (available for the sample characteristics, assets, economic results, farm indicators, production processes, specific analysis on land and transformed productions) by Region and year. The access to the BDR is limited to enabled users who obtain a password after the submission of a specific request or under an agreement (as the case of Universities, research centers or public administrations). Only CREA's internal users and all the external stakeholders belonging to the National Statistical System (SISTAN) are automatically enabled. The database has a high level of detail, even if some variables have been processed by homogeneous categories. Confidential information is not displayed. Information is uploaded every year.
- FADN Database for evaluation: the structure is the same of BDR. The access is restricted to the Regional Statistical Offices that can download only the data included in its own regional dataset. Information is used by public administrations or in analysis inherent the evaluation of rural development measures (ex-ante and ex-post).
- Customized tables: users who need specific variables to perform their analysis can ask FADN data submitting a request form to CREA, processed in few days. In this case, the aggregation level and details depend on the specific request: users could ask data referred to a single variable or, for instance, aggregated by economic size or farm type.
- Prepackaged downloaded tables: a public Datawarehouse is prepared and displayed in a format fitting the general public target audience in a specific web page (Area RICA)[2]. The aggregation level is very high and there are few details regarding the single variables.

1. https://bancadatirica.crea.gov.it/default.aspx.
2. https://arearica.crea.gov.it.

Figure 2 - Tools and public availability of Italian FADN data



Source: own elaboration.

In addition, FADN farmers can download the report of the economic and structural situation of their farm, the financial statement, the sum of costs and revenues, etc., using a personal access. Through their login credentials, farmers can enter in their FADN page (*Cruscotto aziendale*). It is a unique tool, that also provide a benchmark analysis of the single farm with similar farms belonging to the survey.

2. Methodology

According to the Task Force on the Value of Official Statistics, public goods and values related to statistics can be measured considering (i) observable objective indicators such as number of downloads, citations in the media, etc.); (ii) subjective indicators from users' satisfaction survey; (iii) attempt to monetize the value of official statistics (UNECE, 2018).

ISTAT (2019) assesses the value of the public information by mean of subjective indicators based on a users' satisfaction surveys. World Bank (2010) defines its global strategy to improve agricultural and rural statistics on the assessment of the available data users' needs. An investigation of the benefits of FADN has been made through the pattern of publication and known uses (Hill *et al.*, 2016). Specific analysis has been developed looking to the economic values of statistical information: Abbott *et al*, (2016) quantifies this value provided to agricultural corn market while Garcia *et al.* (1997) does the same but referring to the commodity future markets.

The methodology applied in this work has as objective the assessment of the Italian FADN value and benefits through the approach based on the use and users' satisfaction survey.

As previously mentioned, once data is collected, verified, and checked, the dataset is transmitted to the EU Commission and made available at national level in different ways. The BDR and the request of customized tables are the most important instruments, not analyzed until now in any kind of users' inquiry.

Regarding BDR, the only information available concerns a short profile of the enabled accounts in term of affiliation (CREA, public administrations, research centers, etc.). To fill this gap, a questionnaire has been submitted to the enabled users with the aim to collect qualitative and quantitative information on their activities, their expectations, the selectiveness, and reliability of the data supplied, the main uses, and how to improve the system in term of contents and documents. The questionnaire has been sent in an on-line mode (from 13 to 23 May 2020) and included open and close-ended questions.

Another way to make Italian FADN data available to the users is throughout the submission of an online request form in which users can ask the downloading of a set of selected variables in customized tables. The form[3] is divided in three sections: (i) general profile of the applicant; (ii) main use of the requested variables (activity, thematic area of analysis, projects); (iii) requested objects (territorial area, stratification, variables). This application is very common among those users that need partially elaborated information or do not know very well the general structure of BDR. The request is transmitted to CREA that, if necessary, gives further explanations regarding the downloaded data. Data can be stratified by year, farm type and economic dimension, region, agricultural area classes, etc. It is possible a maximum of 5 stratifications and 40 variables in each request. The analysis over this group of users has been made examining all the application forms processed during the period 2011-2020 (first semester).

3. https://rica.crea.gov.it/modulo_richiesta_dati.php.

3. BDR online: use and users

As described, the analysis done on the use and users of Italian FADN has been performed through a questionnaire sent to the enabled accounts. The results are summarized in this paragraph, divided by topics: users' profile, reasons for requesting access, final use of data, most important variables downloaded, clearness of the instruments, opinion on the selectiveness and reliability of the information. It is important to point out that the questionnaire (voluntary) has been sent to all the users regardless to their first date of access to the database. A correct analysis would have required its drafting in parallel to the data use (to avoid omissions or less precision in the most detailed questions), as a pre-requisite to download the data.

In 2020, the users list included 258 enabled accounts belonging to several categories of stakeholders. Most part of them (151) were CREA users; 42 users have been recorded as public administration and local bodies; 36 Universities; 15 research and development agencies, 10 private subjects and 4 agricultural organizations.

In the last two years (2019-2020), 127 users have downloaded data from the BDR (64% from researchers of CREA and 20% from Universities) while the rest has never used data. This is an expected evidence: FADN information is made available in the BDR with the highest complexity and detail level and the targeted audience is represented by the scientific community (mainly academic and researchers).

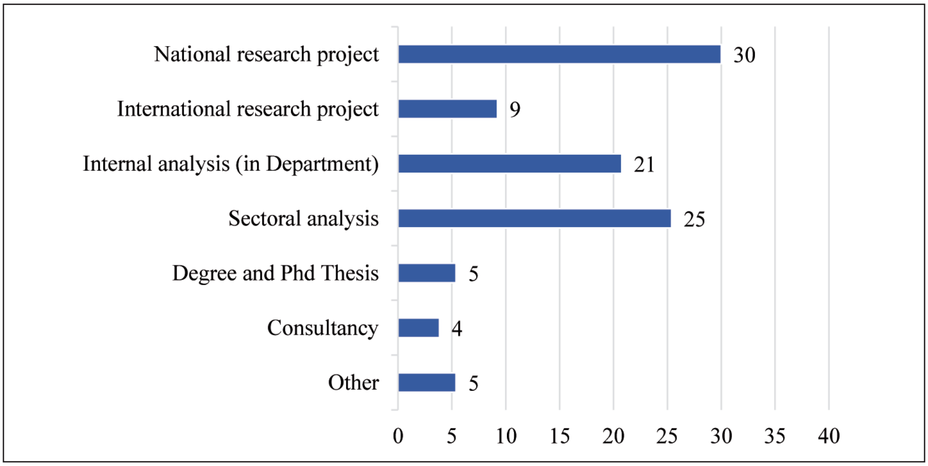
Over 127 users, 59 have replied (47% of the total accession). 88% of them has used directly the BDR data.

The answers are analysed separately.

Use of data: Why did you ask for an access to the BDR?

The Italian FADN is used for several purposes, going from statutory tasks (EU FADN obligations) to policy and impact evaluation analysis. Moreover, the dataset feeds several research projects such as EU FP7, Horizon2020, Phd research, development of models, etc. (Marongiu, 2021). Users were asked to specify this aspect regarding the uses of the FADN in their activity. Over 130 data downloads, 30% have fostered national research projects, followed by sectoral analysis (25%) and internal analysis in specific departments (in Universities or other public administration; 21%). 9% of downloads has fed international research project while is low the use for thesis (5%) or consultancy activities (4%). Probably in this last case, users prefer to get information using the online request form or asking directly to the CREA institute (Figure 3). This result highlights the relevance of the Italian FADN for the public research and, therefore, the importance of the openness policy to guarantee the more widespread and efficient access and the sharing of research data.

Figure 3 - Main uses of the Italian FADN database (% of downloads)



Source: our elaboration on direct survey.

Use of data: Which is the most important information did you have downloaded from the BDR? Which is the most important FADN information in your research sector?

The BDR is organized in tables in which the variables are stored and displayed. The information is grouped by categories (general information about farm, subsidies, livestock, financial statement, certifications, cultivations, labour, buildings and machinery, production, etc.). A close-ended question was addressed to have a general comprehension on the frequency with which the tables were consulted (never, rarely, often) while the information on the most downloaded variables was included in an open-ended question. In general, users are interested to download information regarding (i) general characteristics of the farm; (ii) categories of subsidies; (iii) financial statement (divided in Profit and Loss and Balance Sheet); (iv) cultivations; (v) labour; (vi) farm production. Less interest is played for structural data on buildings, land, and machinery. Tables collecting data on the characteristics of fertilizers and crop protection products are rarely downloaded despite the importance of these variables for environmental analysis. Excluding the annual cost incurred by the farm, collecting specific information is sometimes problematic: differently from the cost, the active ingredients and concentration are not allocated in the single production process, and the toxicity class sometimes can differ for the same products depending on the formulation. For the fertilizers, the unit of nitrogen, phosphorus and potassium is also indicated only for the whole quantity purchased by the farm. Nevertheless, these difficulties, FADN has been used in several works having the environment as main object of analysis (Kelly *et al.*, 2018). Users are often interested in having qualitative information of the seasonal work in terms of country of origin, gender, hours allocated in the production process. Less importance is played by weight and age of livestock, size of the buildings, soil characteristics.

Use of data: Did FADN meet your information needs? Is the general structure of BDR clear and understandable?

Although the Italian FADN collects a wide number of variables (more with respect the EU requirements), the users' information needs result fully satisfied for 58% of respondents. The rest has expressed a partial satisfaction that seems to be not directly linked to the broad spectrum of information available, but rather to methodological issues. The most important concerns elaborated from the open-ended question addressed to the partially satisfied users regard:

- clearness: it is not clear how some variables are calculated, and the unit of measurement is not immediate; for some information there are missing values;
- details: the production costs are not always detailed; the crop variety is not indicated; few information on the water use;
- frequency: the variable has been introduced recently and there is not a time series;
- outliers: many variables have anomalous data that should be deleted;
- reliability: many data seem to be not verified and is not clear if they are reliable and collected in the right way.

This is an important feedback in an improvement perspective. Regarding reliability, it is important to consider the general "environment" in which FADN is developed (Gastaldin and Turchetti, 2021): most part of agricultural holdings have not an accountancy system (compulsory only for the biggest ones). This implies that the whole survey is based on direct interviews, invoices, or related documents, but also on estimations whenever these supporting instruments are not available. Calculating the gross margins by productive process requires the allocation of costs among crops or livestock activities, done by the data collectors often through an estimation of the inputs' distribution. Reliability could be improved adding short methodological explanations where necessary. As concern the outliers, given the high number of variables influencing the agricultural activity, their presence is quite common. To improve this aspect, in 2020 a limited group of significative variables of the BDR (from 2008 to 2019) has been subjected to an outliers' analysis process, performed applying the box-plot method proposed by Tukey (a methodological note is downloadable from the BDR). Users can decide to exclude those farms presenting anomalous data.

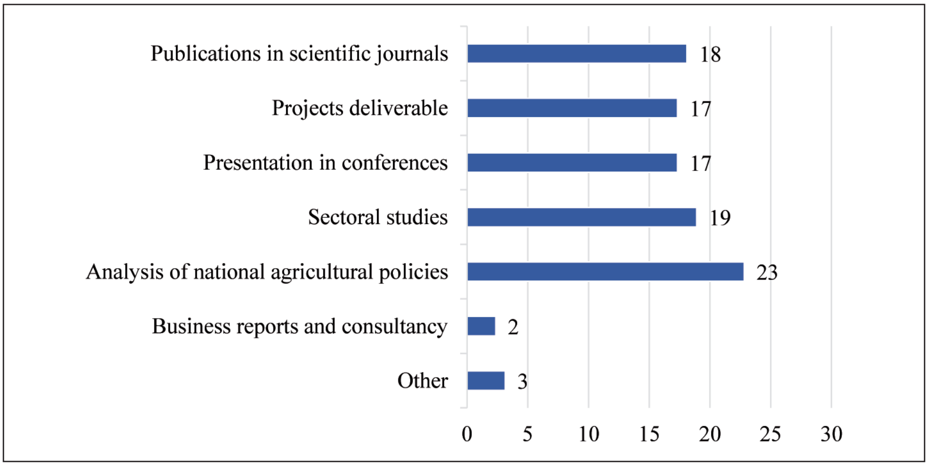
Regarding the clearness, the respondents consider the BDR clear, understandable, and well supported by a documentary system (65%). 35% found some difficulties in a clear comprehension of some sections, because:

- the documentary system is developed outside the BDR so it would be recommended a better integration and/or a direct link of documents with the single table;
- information is stored in different tables with different relationship order (one to one; one to many; many to one);
- the documentary system is clear but not always enough to explain in detail every single variable and the data production (estimation, calculation or derived by other formulas).

Use of data: Which kind of final products and analysis did you perform with FADN data?

40% of respondents use the data as a basis for models or scenario analysis, mainly performed by means of econometric models (44%), efficiency analysis (38%), PMP models (16%). The final scientific production is showed in Figure 4: most part consists in analysis of national agricultural policies (23%) followed by sectoral studies (19%) and publications in scientific journals (18%). Italian FADN is also a basis for project deliverables and presentation in conferences (17%) while is not widespread the use for business reports and consultancy (2%).

Figure 4 - Users' analysis and scientific production based on Italian FADN (%)



Source: our elaboration on direct survey.

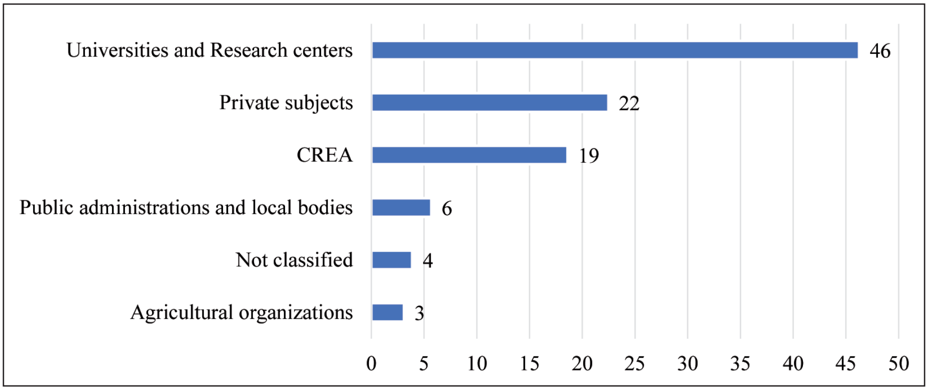
Use of data: Which variables do you consider important for the future research or users' interest?

A specific open-ended question was addressed to have a feedback about the future improvement of the BRD regarding variables not yet collected but potentially valuable in a future perspective. As expected, most of the respondents have mentioned the lack of details concerning environmental and social information. Use of water for irrigation, fertilizers and agrochemicals, data regarding agroecological practices and environmental impact have been claimed as particularly important for the future research needs. For the social analysis, users seem to ask for more details regarding the labour (especially the seasonal work), the social farming, the affiliation to Producers Organizations or other kind of associations, the indication of marketing channels of the single production. In this context, the possibility to add further variables enhancing the analytical and political relevance of FADN and its role in the sustainability assessment is the core of the conversion in Farm Sustainability Data Network (FSDN), an initiative launched within the Farm to Fork strategy, under discussion at European and national level (Gastaldin *et al.*, 2021; Turchetti *et al.*, 2021). This feedback confirms the necessity to improve the current survey framework, adding new variables, deleting those no longer needed or re-arranging and updating those still necessaries.

4. FADN users: analysis of the request forms

The second instrument by which Italian FADN data are disseminated is the request form submitted to CREA. In this case the user has not an access to all the database but can obtain a dataset of selected variables, variously grouped, and organized according to the needs. 387 application forms have been submitted to CREA from 2011 to the first semester of 2020. The profile of users is identified only by means of the affiliation: with respect to the BDR, here the level of detail is lower and users with a specific domain of interests are included like private subjects (22%), national and local public administrations (6%) and agricultural organizations (3%) (Figure 5). Almost half of the requests come from Universities and research institutions (46%) followed by and CREA staff (19%).

Figure 5 - Italian FADN request forms: affiliation of users (%)

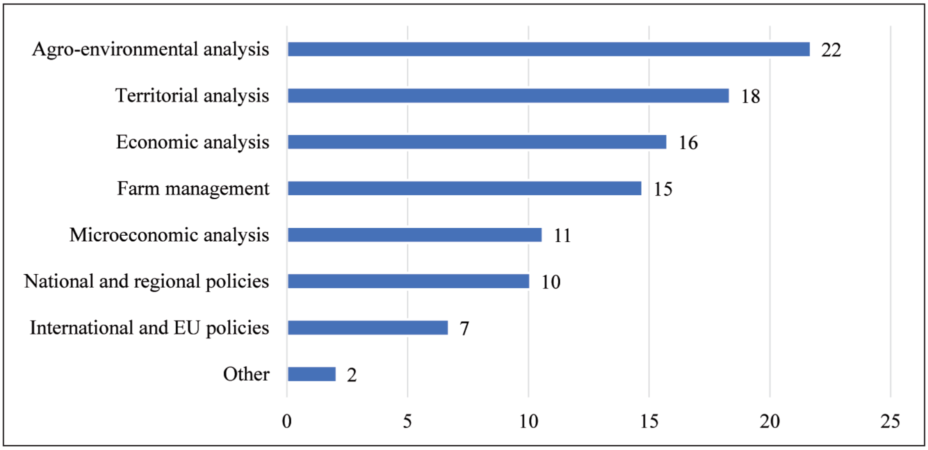


Source: our elaboration on direct survey.

Regarding the final use, 55% of requests has been used for regional analysis and 37% for national analysis. The territorial stratification of the requested variables permits to understand the most frequently analysed local contexts: 25% are required for the north-eastern Italy, 19% for the north-western, 17% for the centre and 39% for southern Italy. The distribution is almost the same among Regions (6-7%).

Differently from what has been highlighted analysing the use of BDR online, in this case data has been exploited mainly for agro-environmental analysis (22%) concerning water management, sustainable productions, emissions and agro-environmental systems. This thematic area has been followed by territorial analysis (18%) focused mainly on farm characteristics. Economic (16%) and microeconomic (11%) analysis and farm management (15%) have been related mainly on farm performance and profitability, production costs and farm assets (Figure 6).

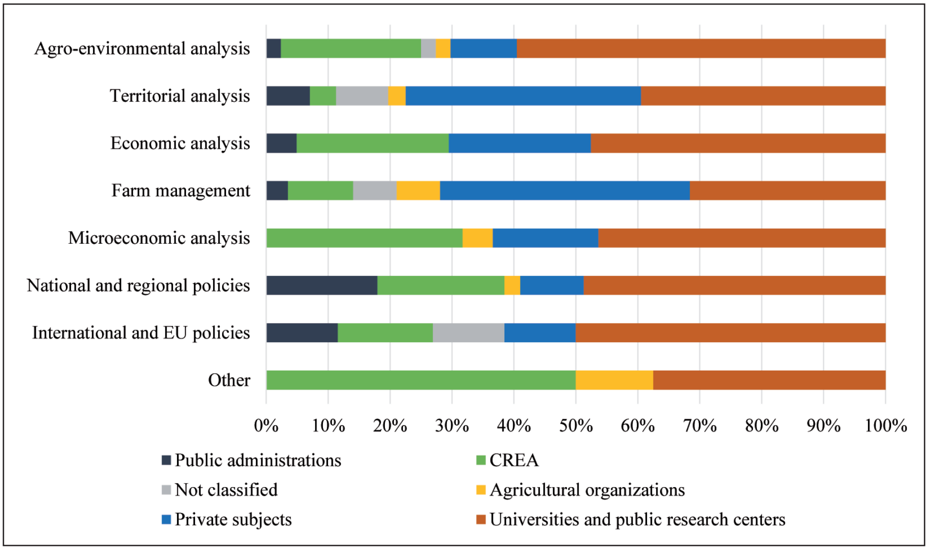
Figure 6 - Use of Italian FADN data by thematic area (2011-2020 first semester; %)



Source: our elaboration on direct survey.

The matching between the affiliation of users and the thematic area under investigation gives an idea about the users' field of analysis. Research from Universities and other bodies covers generally all the thematic areas with a greater attention for the agri-environmental aspects and policies. Administrations and local bodies are focused mainly of the variables for EU, national and regional policy analysis. Advisors (included in the private subjects) and agricultural associations ask for farm management data, economic and territorial analysis while the requests from CREA researchers concern mainly variables for microeconomic and agri-environmental analysis. With respect to the BDR, advisors seem to be more oriented to ask FADN data using the request form, and this is also an important aspect to consider in future: strengthening the use of data in farm advise could reinforce farmer's incentive to participate in the survey.

Figure 7 - Information requested by thematic areas and users



Source: our elaboration on direct survey.

5. Final remarks

The main objective of the Italian FADN is the collection of economic information on the national agricultural sector. This information is mandatorily sent to the European Commission but also made available at national level through several kind of tools characterized by an increasing level of aggregation, detail, and complexity according to the targeted audience. Being funded by public money, Italian FADN is considered as a public good and the information is made available for research, scientific or policy activities. Over the years, the database, and the whole IT system (server, software, data management, etc.) has evolved: (i) new tables and sections have been added, (ii) data are available and downloadable directly by the users or through customized tables grouped by region, type of farming and economic size, (iii) methodological notes and reports clarify the structure of the survey. The survey has gained a greater value since it has been used by a broad range of public and private researchers, for socio-economic and policy analysis, and for knowledge to the general public. Benefits and impacts of this system have been analyzed for the first time in this work through a users' satisfaction survey, that is considered a subjective way to evaluate benefits and value of this kind of public goods. The descriptive analysis of the results confirmed the importance of the Italian FADN in promoting the public research, encouraging diversity of analysis, and making possible the application of different methodologies and models. Universities and research centers are the most important "consumers" of FADN data, used to perform national and international analysis published often in open access scientific journals, project deliverables and conference proceedings. This increases the benefits and the public importance of data access, giving a contribute to the general knowledge system. The provision of customized tables based on a set of specific variables asked by the users through a request form is another way to obtain FADN data: this dissemination method permits to broaden the base of users, enlarging it also to those who do not have a deep knowledge of the FADN structure. Private subjects, agricultural organizations and local bodies ask accession in this way.

Less frequent is the use for farm advice, that must be strengthen in future not only as incentive for farm's participation in FADN but also to reinforce the use in the Agricultural Knowledge and Innovation System (AKIS). Another important point raised in the survey concerns the opportunity to enable the exploration of new topics and the enhancement of data collection methods and measurement. 58% of respondents was fully satisfied from the use of the FADN database but the partial satisfaction seemed to be more related to methodological issues (clearness and reliability) than on the lack of data. Moreover, several variables have been considered important in future perspective, namely environmental and social information. Despite the higher number of information gathered by the Italian FADN comparing the mandatory scheme, the importance to integrate the actual survey system with additional variables related to the environmental and social aspects of farm management is emerged as an important feedback. This option is currently under discussion and the likely conversion of FADN in FSDN will have implication in all the Member States. Adding further variables means additional efforts in collecting, checking, validating the data and requires a higher trust between farmers and data collectors, as stated in some study (Vrolijk *et al.*, 2016). A feedback over the users' satisfaction has been pointed also regarding the clearness of the BDR.

Although this first work has been limited to inquiry some aspects of use and users of the Italian FADN, it is considered an important step to track the uses, better framing the final products. This is a first attempt, but it would be recommended to monitor systematically the FADN users in each access. The questionnaire could be more fully structured to collect further information on specific characteristics of respondents like age, educational level, knowledge of FADN, etc. It may be appropriate also a short inquiry over the Datawarehouse to have some idea about the satisfaction of the general public and the level of dissemination.

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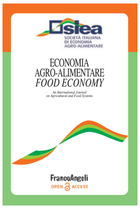
Economia agro-alimentare /
Food Economy

An International Journal on Agricultural and Food Systems

Vol. 23, Iss. 3, Art. 11, pp. 1-32 - ISSN 1126-1668 - ISSNe 1972-4802
DOI: 10.3280/ecag2021oa12766



Financial sustainability in Italian Organic Farms: an analysis of the FADN Sample

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Abstract

With the European Green Deal, presented in December 2019, the EU Commission aims at making Europe the world's first climate neutral continent by 2050. In this plan agriculture plays a key role and so does organic farming. The aim of this work is to assess the financial sustainability of organic farms compared to conventional ones, measuring the liquidity they generate, evaluating its adequacy and identifying the factors that influence its extent. Specifically, this study uses the Italian FADN sample, made up of 18 TFs, and measures the Free Cash Flow on Equity (FCFE) for both organic and conventional farms. The econometric analysis identifies the variables contributing to cash flow production and is based on three types of variables: structural, including the cash flow itself, relative to farm results. The analysis showed that financial sustainability is greater for organic than conventional farms, and in several cases the level reached by the former is very high especially in mixed TFs. Yet, a major part of the sustainability of organic farms is due to EU payments, mainly of the CAP II type. Also, the balance of business relationships with customers and suppliers allows organic farms to increase liquidity almost as much as the total amount of public aid received. Still, this result should be supported by improving price and yield conditions, as much of the GMO is achieved with below-average value for both variables. Finally, our analytical approach can be used by Countries using the FADN to assess the situation of their agriculture and help direct policy support better.

Article info

Type:
Article
Submitted:
14/05/2021
Accepted:
10/09/2021
Available online:
12/01/2022

JEL codes:
C01, Q12, Q14

Keywords:
Financial sustainability
Cash flow analysis
Regression analysis
Organic farming
FADN
European Rural Development Policy

Managing Editor:
Lucia Briamonte,
Luca Cesaro,
Alfonso Scardera

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Introduction

The *European Green Deal*, presented by the EU Commission in December 2019, is an ambitious plan whose goal is to make Europe the world's first climate neutral continent by 2050. In this plan agriculture plays a key role, as shown by *From Farm to Fork Strategy* that aims at a "*fair, healthy and environmentally-friendly food system*" (CE, COM/2019/640 final). More specifically, by 2030, EU aims at a 50% reduction of the use and risk of chemical pesticides, and at least 20% reduction of fertilisers, as well as a 50% reduction of the sales of antimicrobials for farmed animals. In this context, the goal is to expand at 25% European agricultural land under organic farming. Today in Italy nearly 14% of UAA is under organic farming, mostly located in Southern Italy (CREA, 2020). Yet, the area under conversion in the last three years has been reduced by 15%, which is hardly in line with the EU's objective. On the other hand, domestic Italian consumptions for organic food increased by 4.4% only in the first half of 2020, exceeding 3.3 billion of euros (SINAB, 2020). The organic market continues to grow (notably farmers who also process the product) and the Italian sector seems to have absorbed the impact of the pandemic better than the rest of the agri-food system (CREA, 2021).

Krause et Spicka (2017) and Rana et Paul (2017) highlight that consumer purchasing choices are ever more guided by considerations on food quality and safety, as well as on the environmental impact of food production, which is especially true for some age groups and territories. According to CREA (2021), despite a minor increase in the last period, the search for a healthy diet continues to increase the propensity of Italian consumers to buy organic foods, especially white meats, whole foods, and legumes. Furthermore, during the COVID-19 crisis, the purchases of these products in large-scale distribution increased (+11%), which contributed to expanding the market beyond the classic niche sales channels and specialized stores. The purchasing model of organic products is also changing, becoming more frequent and recurrent (SINAB, 2021). According to Furno *et al.* (2021), sector operators should adapt their marketing strategies in the various market segments to these trends.

Taking advantage of this growing market isn't always easy for local producers and the literature highlights various issues of sector development. According to Hanson *et al.* (2004) organic farmers, in addition to the typical risks of agriculture, also face sector-specific risks such as those of transition, soil conservation, crop protection from GMO contamination, as well as increased price volatility. In this regard, Berentsen *et al.* (2012), underline that the production risk of organic cow's milk is greater than in the conventional sector because sales take place in niche markets where prices are volatile, moreover in a context of much lower yield. Furthermore, the fragility of the production system can be amplified by the physical-climatic characteristics of some territories, making uncertain the adequacy of the economic awards for the efforts made (Seufert *et al.*, 2012; Cisilino *et al.*, 2019). Pimentel *et al.* (2005) also underline that, with the same production orientation, the organic method requires a greater amount of work than conventional management. This is accompanied by the need to adopt specific varieties and soil management practices as well as to respect constraints to the use of chemicals that make the daily management of the organic farm completely different from the conventional one (Ponti *et al.*, 2012; Bueren *et al.*, 2011; Bouttes *et al.*, 2019; COM, Reg. n. 889/2008, COM, Reg. n. 1584/2018). To this evidence Crowder and Reganold (2015) contrast the lower operating costs per hectare that would lead organic farms to have greater profits. Still, according to Home *et al.* (2018) the modest increase in the number of organic farms suggests that profit maximization is not enough to push farmers towards this method, but other factors must be considered as those relating to legislation and policy. Besides, according to Abele *et al.* (2007) and Bennett and Franzel (2013) the benefits of selling organic products go largely to intermediaries and traders, while exporting to richer markets is only accessible to larger farms (Tovar *et al.*, 2005) As a result, the difficulty in converting from conventional to organic is considered an important barrier especially for small and medium-sized farms (i.e., almost all Italian farms) and farmers' concerns may outweigh the benefits of embarking on a new management method (Łuczka et Kalinowski, 2020; Kallas *et al.*, 2010; Jouzi *et al.*, 2017). In this context, Willer *et al.* (2017) claim that the lack of information on the economic performance of organic farms, as well as research on key inputs and the challenges that they face, hinder the exploitation of the growing demand for organic products. The possibility of limitations in the use of chemicals in European agriculture makes it even more urgent to frame and analyse the conditions of the economic and financial sustainability of organic farming.

The aim of this work is to explore the issue of financial sustainability of organic farms compared to conventional ones, measuring the liquidity they generate, evaluating its adequacy and identifying the factors that influence its extent. The economic literature shows that the study of cash flows defines the financial constraints of the firm, measuring how much it depends on internal funds. The firm's relationship with these constraints helps to explain its investment decisions, the ability to obtain credit and, therefore, finance the investments (Fazzari *et al.*, 1988; Kaplan and Zingales, 2000; Mulenga and Bhatia, 2017). Several studies agree that defining a firm's financial profile reveals its ability to repay the loans (McNamara *et al.*, 2015) and to support its investment plans when, in case of credit crunch, internal funds remain the main, if not the only, source of financing. Dono *et al.* (2021) show the conditions for Italian agriculture as a whole and for its various production sectors, identifying financial sustainability as the ability to offset the farm production system depreciation with the generated cash flow, as identified by the Free Cash Flow on Equity (FCFE). A result of that study is a dichotomy between specialized Types of Farming (TFs), which largely achieve FCFE/depreciation ratios greater than 1, sometimes even a great deal, and other TFs, largely unspecialized, which generally present values of that ratio below unity. The latter TFs represent a relevant component for employment, production, and agricultural income in Italy, which makes it interesting to further explore the characteristics of this dichotomy. This study deepens that analysis by examining how organic farms fit into the dichotomy between highly and poorly financially sustainable TFs of Italian agriculture.

Specifically, the study uses a constant sample of farms from the Farm Accountancy Data Network (FADN) divided into organic and conventional farms to analyse and compare the achieved financial sustainability condition. This does not require assessing the production efficiency of conventional and organic methods but measuring their cash flow generation as a basis for comparing their financial, structural, and operational conditions. The analysis highlights the position of organic farms in 18 TFs that represent the main productive orientations of Italian agriculture. Then, using the classic elasticity measurements obtained from the regression analysis of Dono *et al.* (2021), the study identifies and compares the influences of structural and economic variables on the production of cash flows in organic and conventional farms. Indications emerge on the differences in financial sustainability and on the factors that influence it in the studied groups.

The next paragraph exposes the materials and methods, first describing the general characteristics of the sample of farms of which it highlights the general representativeness and the weight of the organic farms in it. Then, we describe the sequence of operations to calculate the cash flows and the characteristics of the econometric model that establishes the influence of a group of explanatory variables on those flows. The section on results follows, which first shows the levels of FCFE and the relationships with depreciation distinguishing between the two methods, the single TFs, and three of their clusters: poor, medium and high sustainability. For these various aggregates, the elasticities and their components are then reported as indicators of the influence of the explanatory variables on the generation of cash flow. The discussion and the conclusions sections follow.

1. Materials and methods

1.1. *General characteristics of the sample of farms*

We analyse the financial sustainability of Italian organic farms based on the constant sample of FADN data used by Dono *et al.* (2021). The FADN was established by the Reg. 79/65/EEC, updated by Reg. CE 1217/2009, and annually collects technical and economic data of a large farms sample following a similar approach in the European Union countries. The more than 86,000 FADN farms represent nearly 5 million farms in the EU, 90% of the Utilized Agricultural Area (UAA) and 90% of Standard Production. Currently the Italian sample is based on about 11,000 farms and covers more than 90% of the UAA, Standard Production, Work forces and Livestock Units. About 1,000 variables are recorded for each farm in the sample, more than 2,500 for the Italian FADN. The FADN sample only includes professional and market-oriented farms and is stratified by region, economic size class and Types of Farming according to Reg. CE n. 1242/2008, henceforth TF. The farms are assigned to a specific TF based on the prevalence of the standard productions of cultivation and livestock rearing conducted in a year. The TFs are divided into 3 levels with progressive ramifications: 8 classes of general basic TFs[1]; 21 branches of principal TFs; 61 further particular TFs.

Based on these data, Dono *et al.* (2021) obtain three years of financial statements (2014-2016) for a constant FADN sample consisting of 4,612 Italian farms, for a total of 13,836 observations. FADN classifies as organic also farms in conversion: these include farms that already carry out activities in organic and are extending this method to their other activities (63 observations in the sample), as well as farms that are converting exclusively from conventional (21 observations)[2]. The issue of conversion to organic should be evaluated on this second type. Yet, the low number of observations in the sample prevented a large development of this analysis. Table 1 shows the relative weight of conventional and organic farms, including farms in conversion, for important production and income variables. Organic farms are 13.1% of the total (1,812 observations) and represent 14.1% of the UAA and 12.2% of the Gross Capital. They also produce 10.8% of operating income and represent 11.5% of family farm work.

1. Specialist field crops, Specialist horticulture, Specialist Permanent Crops, Specialist Grazing Livestock, Specialist granivores, Mixed Cropping, Mixed Livestock, Mixed crops Livestock.

2. FADN also defines as organic conventional farms whose production is only partially organic. Yet, for every farm, it provides details about products and certifications, and this allowed us to identify farms whose certification is defined as "mixed (organic processes mixed with conventional processes)" and/or whose products are defined as derived "from land under organic conversion".

Table 1 - Operating Income, Gross Capital, Family Work Forces, UAA and Farms as percentage on total sample for Conventional and Organic farms

	Operating income	**Gross capital**	**Family work forces**	**UAA**	**Number of farms**
Conventional	89.2	87.8	88.5	85.9	86.9
Organic	10.8	12.2	11.5	14.1	13.1

Source: FADN data (our elaboration).

1.2. *The calculation of cash flows*

Table 2 shows how the various farm activities generate cash flows. These are obtained by starting to subtract the tax component from the Operating Income, then by adding depreciation, provisions for severance pay and for risks and other expenses. The *variation of net working capital*, as made up of operating receivables with customers and operating payables with suppliers is then added. The same is done with *investments*, obtained as increase of inventories net of their depreciation, to generate the *Cash Flow From Operations*. FCFE is calculated by adding to the latter the balance of relations with the farm's financiers: where paying interest and principal on debts falling due in the year reduces liquidity, while obtaining new loans increases it. Public aid from the second pillar of the CAP and other national measures also increase liquidity, as well as revenue from other current accounts or other income, such as financial assets or divestments. Paying fines and repaying other loans reduces liquidity. This sequence generates a monetary liquidity variable that still includes payments to work, and the capital resources provided by the farmer: it plays a central role in the analysis and has been called CAFFE (*Free Cash Flow to Equity + Farm Family Earnings*). The final cash flow is obtained by subtracting cash withdrawals to pay for the farmer's resources: Dono *et al*. (2021) estimated these *Farm Family Earnings* at opportunity cost values and deducted from CAFFE to obtain the *Free Cash Flow to Equity* (FCFE). Yet, this is an approximation since the farmer does not necessarily collect opportunity cost payments for the resources provided as, moreover, it also happens in the case of the distribution of corporate dividends (Chay & Suh, 2009).

Table 2 - FCFE Calculation: formulas and FADN Databases (FDB) used

Income and cash flow items	FDB	NOTE
Operating income		
– Taxes	IS	
+ Depreciation		
+ Other provisions	BS	Δ (employee leaving indemnity fund + other funds)
± Δ Net working capital	BS	Δ (debts + credits + product stock + raw materials stocks)
– Investments		
Cash Flow From Operations (CAFFO)		
± Principal portion	BS	Δ medium/long term debt
– Interest portion		
+ Public aid	IS	EU second pillar aid and other national aid
+ Other receipts		
Free Cash Flow + Compensation to Farmer resources (CAFFE)		
– Payment to capital	BS	% of net capital
– Compensation to managerial work	IS	% of gross marketable output
– Compensation to manual labor	Lab	hourly wages for hours of family work
Free Cash Flow to Equity (FCFE)		

(IS) = Income Statement; (BS) = Balance Sheet; (Lab) = Labor file; D = variation over the year.

Financial sustainability is achieved when FCFE is greater than the depreciation of productive capital, even by a margin that can also repay a debt service provided at a subsidized rate. This indicator can be traced back to the financial analysis of the debt of the company that Bonazzi and Iotti apply to the tomato processing industry, aquaculture, and dairy cattle breeding in Italy (Bonazzi and Iotti, 2014a, 2014b, 2015a, 2015b; Iotti and Bonazzi, 2015). These authors calculate the financial sustainability of investment debt by relating its cost to the cash flows generated by various level of the operating activities[3]. Obviously, these indicators can be calculated only in relation to specific investment programs that are in place only in a part of the FADN farms. To carry out a general financial sustainability analysis for all farms, Dono *et al.* (2021) assess whether the final monetary liquidity surplus given by FCFE is sufficient to balance the residual implicit costs, i.e., the depreciation of technologies and provisions for risks or other funds. The index does not check whether the farms will reproduce the

3. Bonazzi and Iotti (2014b) consider, among others, the Operating Cash Flow, and the Unlevered Free Cash Flow, which subtracts the investment and adds the divestment to the former.

initial capital or not. Depreciation, in fact, is calculated at historical cost, which in the case of old plants can make the current restoration cost even very different from that associated with depreciation. Furthermore, new market, policy support and production technology conditions may not induce farmers to restore the original system. Thus, the index verifies a minimum sustainability condition, defined as weak, which reveals whether farms are generating additional cash flows at the same rate at which their technological system depreciates. Moreover, unlike the economic valuation indices, its financial components allow it to also embody the investment efforts of farms, as well as their commercial and financial relationships. Dono *et al.* (2021) calculate the index for the whole sample and for 18 TFs that aggregate the original particular FADN TFs. Table 3 shows the values of the indices and the percentage weights of the various TFs. For the purposes of our analysis, the TFs are divided into three clusters based on their financial sustainability condition.

Table 3 - TFs and clusters of TFs with percentage on total sample

Cluster	TFs	% on total sample	FCFE/ Depreciation
Poor general sustainability	Mixed Crops and Livestock	3.23	–0.08
	Extensive Beef Cattle	5.98	0.10
	Mixed Crops	6.07	0.38
	Mixed Fruits	10.78	0.80
	Arable Crops	21.96	0.82
	Sheep	5.20	0.87
	Dairy Cattle	8.74	1.15
Medium general sustainability	Vineyards	12.16	1.19
	Mixed Livestock	2.15	1.42
	Greenhouse Vegetables	0.91	1.44
	Olive Growing	3.84	2.08
High general sustainability	Swine	1.82	2.42
	Other	6.14	2.65
	Poultry	2.43	3.90
	Citrus Fruits	1.60	4.12
	Open Field Vegetables	4.51	4.48
	Fruits in Shell	0.82	6.86
	Intensive Beef Cattle	1.65	7.08
Total		**100.00**	**1.57**

Source: FADN data (our elaboration).

Specifically, the *poor general sustainability* cluster has index values below 1.15 and coincides with the area of financial difficulty identified by Dono *et al.* (2021). This cluster includes major specialized TFs, such as *dairy cattle*, which are in a border condition, *sheep*, and *arable crops*; however, most of these TFs are extensive and unspecialized. The *medium general sustainability* cluster has index values between the 1.15 and 2.10: it includes TFs specialized in activities that are very typical of Italian agriculture, such as *vineyards*, *greenhouses* and *olive growing*. The *high general sustainability* cluster has index values exceeding 2.10 and includes TFs of high income and peculiar production conditions, such as *fruits in shell*, *intensive beef cattle*, *poultry*. The adjective general of these definitions refers to the condition of the clusters for the whole of Italian agriculture: in the following it will be deleted since the specific condition of organic farms and the rest of agriculture do not always correspond.

1.3. *Econometric estimate of the formation of cash flows in Italian farms*

The econometric analysis to identify the variables that contribute the most to generating cash flows was based on three types of regressors, reported in Table 4.

Table 4 - Variables used in the econometric model

	Structural variables	
Farmland	Value of owned land	} at the beginning of the year
Inventories	Value of stocks of productive factors and products	
Depreciable	Value of depreciable capitals land	
	Variables composing the Cash Flow	
Investments	Increase in the value of the capital net of depreciation	at the end of the year
CAP I	EU first pillar aid	from the total farm revenues
CAP II	EU second pillar aid and other national aid	from extra-characteristic management
Δ Working Capital Change	Δ (debts + credits + product stock + raw materials stocks)	end - beginning of the year difference
	Farm results variables	
ROI	Efficiency index computed at the same opportunity cost used for FCFE	
Price Advantage	Difference in the prices of the farm over territorial average	From implicit prices of products
Yield advantage	Difference in the yields of the farm over territorial average	From products yields

The first group indicates the influences of the structural endowments of farms, defined as values of owned *farmland*, *inventories*, and *depreciable* assets. Then there is the group of variables that directly constitute the cash flow, namely: annual *investment* value, *CAP I* and *CAP II* payments; changes in operating working capital (Δ*WCC*). Finally, there are the variables relating to the level of efficiency of the farm and some of its market and production results, namely: the Return on Investment without CAP first pillar aid (*ROI*)[4]; *price advantage* is the difference in Gross Marketable Output (GMO) of each farm at the observed implicit prices of its products, and at the arithmetic mean of these prices in the geographic area where the farm operates; *yield advantage* is the difference in GMO of each farm at the observed yields of its products, and at the arithmetic mean of these yields in the geographic and altimetric area where the farm operates[5]. All these variables were divided by the family work units available in the farm to consider that in most Italian farms, classified as single or simple company, business and entrepreneur are identified. This causes the productive and reproductive spheres to overlap, placing the business risks precisely on the family, that is, on the farmer and his family assistants (Corsi and Salvioni, 2012; Davidova and Thomson, 2014). Hence, it seemed relevant to assess the generation of cash flows with respect to the work provided by the farm family. Later we will keep the names listed above also for the variables obtained with this standardization.

The influence of these variables on CAFFE were represented with a quadratic functional form which, with its typical curvature, fits the data with flexibility and allows non-linear relationships, in which the effect of an explanatory variable depends on the values it assumes. Specifically, the quadratic term allows representing the curvature of the function, which denotes the weakening or intensification of the influence of the explanatory

4. ROI is an indicator of farm efficiency based on Operating Income, which reflects the effect of managing operational activities. Instead, ROE includes the income from extra-typical activities, that in agriculture do not depend on farmer decisions, i.e., taxation (Fontana, 2017) or depend on long-term decisions (interest or contributions for investments). Like FCFE, ROI calculation uses opportunity cost compensations for the labour resources of the farmer and his family.

5. The arithmetic averages of the implicit prices of the various farms are calculated on North, Centre, and South macro-areas (arithmetic average of the implicit prices of tomatoes in Southern farms). The implicit price of meat derives from the ratio between the gross profit of the stable and the number of animals of the farm. For the other animal products, the gross saleable production (GSP) and the quantities of milk (cattle, buffaloes, sheep, goats), or GSP and the number of animals (chickens, bees) are reported. Altimetry is also considered for average yields, with Mountains, Hills, and Plains (arithmetic average of tomato yields in the farms in the southern plain). For meat, eggs, and honey it was not possible to calculate the average yield and only the saleable production at the observed yields was considered. As with implicit prices, the average yield value is an arithmetic average of the values of individual farms.

variable. The existence of the misspecification due to *endogeneity* was verified with the Hausman test and consequently corrected. The model estimates of the coefficients were used to calculate the classic elasticity indicator that represents CAFFE's response to each regressor in the analysis. For the generic regressor $\boldsymbol{x}$ this indicator is expressed as:

$$\boldsymbol{\varepsilon_{\overline{x}}} = \frac{\Delta\%\, \boldsymbol{CAFFE}}{\Delta\%\, \boldsymbol{x}} = \frac{\Delta \boldsymbol{CAFFE}/\overline{\boldsymbol{CAFFE}}}{\Delta \boldsymbol{x}/\overline{\boldsymbol{x}}} = \frac{\Delta \boldsymbol{CAFFE}}{\Delta \boldsymbol{x}} \cdot \frac{\overline{\boldsymbol{x}}}{\overline{\boldsymbol{CAFFE}}}$$

The elasticity, i.e., the reactivity of CAFFE to the various regressors, is made up of two components. First, the slope of the function indicates the ability to generate CAFFE by varying the endowments of the capitals, the farm efficiency level, the price, and yield advantages. For the variables that flow into CAFFE, it identifies the net share of the regressor that becomes cash flow. Second, the ratios of the regressors values on CAFFE indicates the relative importance of the regressor or, equally, the ability to produce CAFFE with the equipment or levels assumed. The elasticity, the slope of the tangent and the weight of the regressors on CAFFE are calculated at the mean value of the variables.

2. Results

2.1. *General conditions of sustainability*

Table 5 presents for each TF and their aggregates: the percentage of organic and conventional farms; the cash flow value per unit of family work; the value of the financial sustainability index (F/D = FCFE/depreciation). The value of F/D of the entire sample is 1.57, indicating that, on average, FCFE balances capital depreciation and generates a surplus of liquidity to pay any financial charges of the reconstitution. Table 5 shows that F/D is 2.10 in organic farms and 1.50 in conventional. The data also show that the various TFs and their clusters present different positions of organic farms, even opposite to those in conventional. Let's see the situation for the three clusters.

The *poor sustainability* cluster represents 62.0% of the sample (Table 3) and organic farms make up 12.4% of it (Table 5). The sustainability condition is favourable for organic farms (1.66), poor for conventional ones (0.66). The former group generates more liquidity than the latter, which applies also to the various TFs, excluding *dairy cattle*. Similarly, the index is greater than 1 in most of the TFs in organic farming, while it is lower than 1, and with negative values, for most of the conventional ones. Exceptions are *sheep*,

Table 5 - Percentage on total sample, of Organic (O) and Conventional (C) farms, FCFE and FCFE/Depreciation for TFs and their clusters

	% on TF		**FCFE**		**F/D**	
	O	**C**	**O**	**C**	**O**	**C**
Mixed Crops and Livestock	11.9	88.1	42,100	–6,519	2.75	–0.75
Extensive Beef Cattle	17.0	83.0	10,455	–1,098	1.23	–0.13
Mixed Crops	16.2	83.8	16,268	195	1.71	0.03
Mixed Fruits	17.2	82.8	19,540	3,052	3.25	0.40
Arable Crops	7.5	92.5	21,711	5,278	2.71	0.66
Sheep	23.2	76.8	13,498	7,083	0.94	0.83
Dairy Cattle	6.4	93.6	–2,364	26,573	–0.11	1.24
Vineyards	9.4	90.6	16,627	8,605	1.46	1.14
Mixed Livestock	10.8	89.2	106,810	2,398	9.28	0.26
Greenhouses Vegetables	7.1	92.9	34,004	17,482	1.67	1.41
Olive Growing	49.9	50.1	11,516	10,086	2.49	1.75
Swine	1.2	98.8	34,723	82,789	5.91	2.41
Other	5.8	94.2	19,800	15,316	1.81	2.75
Poultry	6.3	93.8	8,837	62,303	0.81	4.04
Citrus Fruits	55.4	44.6	33,187	10,517	5.24	2.24
Open Field Vegetables	9.0	91.0	22,000	44,940	1.72	4.86
Fruits in Shell	20.2	79.8	82,256	23,238	9.12	5.61
Intensive Beef Cattle	7.0	93.0	–5,713	143,296	–0.47	7.44
Poor Sustainability	12.4	86.9	16,963	6,575	1.66	0.66
Medium sustainability	17.6	80.4	20,265	8,508	2.63	1.09
High Sustainability	11.1	93.3	28,778	47,795	3.12	3.98
Total	**13.1**	**86.9**	**19,703**	**14,927**	**2.10**	**1.50**

Source: FADN data (our elaboration).

which show similar results in both methods (0.94 vs 0.83) and *dairy cattle*, whose conventional farms show the best result of the group, while organic farms have the worst result (–0.11 vs 1.24).

The *medium sustainability* group constitutes 19.1% of the sample and has a higher percentage of organic farms (17.6%), which generate considerable liquidity and reach a high level of sustainability. Moreover, organic farms show better results than conventional ones in all TFs, with the excellent performance of *mixed livestock* (9.28).

The *high sustainability* group represents 19.0% of the sample and organic farms are a clear minority of it (11.1%). The organic farms results are better than the results showed by the previous clusters, even if this is the only group where conventional farms are more sustainable than organic ones. Indeed, the absolute value of FCFE in organic is lower especially for *poultry* (0.81 vs. 4.04) and *intensive beef cattle* (–0.47 vs. 7.44), that are unsustainable in organic but show high index values in conventional. Conversely, organic farms show their highest sustainability in *fruit in shell* (9.12 vs 5.61) and *citrus fruits* (5.24 vs. 2.24)[6].

2.2. *Elasticity*

The elasticities of CAFFE reflect the influence of the regressors on the ability of the farms to generate cash flows, which depends on the slope of the function and on the weight of the variable over CAFFE. Table 6 reports the average elasticities for the various clusters of the organic and conventional farms. The values are shown by type of regressor: structural features of the farms (*farmland, inventories, depreciable*), cash flow elements (*Investments, CAP I, CAP II, ΔWCC*), economic and productive results (*ROI, price advantage, yield advantage*).

Table 6 - Average elasticities for Total Sample and for groups of TFs

TFs	Farm-land	Invento-ries	Depre-ciable	Invest-ments	CAP I	CAP II	ΔWCC	ROI	Price Advan-tage	Yield Advan-tage
Poor	0.72	0.14	0.002	–0.19	0.17	0.08	0.19	–0.11	–0.07	–0.02
Medium	0.81	0.18	0.003	–0.42	0.26	0.14	0.00	–0.30	–0.01	–0.02
High	0.71	0.09	0.001	–0.16	0.14	0.14	–0.05	–0.15	–0.08	–0.36
Organic	**0.74**	**0.14**	**0.002**	**–0.23**	**0.19**	**0.10**	**0.12**	**–0.15**	**–0.06**	**–0.06**
Poor	1.19	0.21	0.004	–0.49	0.29	0.07	0.02	–0.32	–0.05	–0.01
Medium	1.01	0.42	0.002	–0.44	0.12	0.05	–0.03	–0.23	–0.04	–0.02
High	0.37	0.30	0.002	–0.14	0.11	0.02	0.00	–0.05	–0.23	–0.15
Conventional	**0.88**	**0.30**	**0.003**	**–0.36**	**0.20**	**0.05**	**0.01**	**–0.21**	**–0.11**	**–0.06**
Total	**0.85**	**0.27**	**0.002**	**–0.33**	**0.20**	**0.06**	**0.03**	**–0.20**	**–0.10**	**–0.06**

Source: FADN data (our elaboration).

Table A1 in the Appendix reports the elasticity to regressors for all the TFs and the clusters. Table A2 reports the slope of the function, indicating how much of the variable converts into cash flow at the average values. Table A3 reports the weight of the regressor, indicating its relative

6. Also, *swine* shows excellent results both in organic and in conventional (5.91 vs. 2.41) but with a very small number of observations for organic farms.

importance on CAFFE; its reciprocal indicates the ability, or productivity, of the regressor in generating cash flow.

2.2.1. Structural variables

For both organic and conventional methods, the regressor with the higher elasticity, and impact, on cash flow is *farmland* (Table 6), due to the high incidence of this endowment on CAFFE (Table A3). Conventional farms are more responsive to changes in *farmland* due to the greater weight of the regressor. The reciprocal of the ratio also indicates that these farms produce less CAFFE per unit of the resource. Organic farms, instead, produce more CAFFE per unit of *farmland*, which makes them less responsive to its variations. This productivity gap of farmland between organic and conventional is accentuated in the clusters with *poor* and *medium sustainability*, especially in the TFs *arable crops*, *mixed fruit*, *mixed crops*. The situation is opposite in highly sustainable cluster, where organic farms require more land than conventional ones to produce one unit of CAFFE. The slope of the function is similar in the two groups, and this indicates that about one-tenth of the variation in farmland results in a variation in CAFFE (Table A2).

Inventories elasticity is lower than for *farmland*, especially due to the lower weight of the endowment of this capital on CAFFE. Then, in organic farms this weight is less than in conventional ones, which further reduces its elasticity (Table A3)[7]. This lower weight is found for all organic clusters: it indicates a higher average productivity of *inventories* in terms of CAFFE, marked for high sustainability TFs. Again, the slope of the function is the same for the two methods and indicates that more than 40% of the change in this asset endowment translates into a change in CAFFE. The value of the slope reveals that varying the *inventories* endowment modifies the value of CAFFE more consistently than a similar variation in *farmland* (Table A2).

Depreciable elasticities of the three groups are also similar. Their low value depends on the very low slope of the function, indicating that less than 2‰ of the variation in the asset results in a variation of CAFFE (Table A2). On the other hand, the endowment of this asset per unit of CAFFE is higher than that of *inventories*. Yet, the comparison between the two methods shows that the endowment of this capital per unit of CAFFE is lower in organic farms, i.e., the average productivity of this capital is higher in organic than in conventional farms (Table A3). Exceptions are *dairy cattle*

7. Inventories average value for organic *Swine* and *Fruits in Shell* is equal to zero, thus their elasticities are not available.

and *greenhouse vegetables*, whose high endowment of *depreciable* makes the relative elasticity of organic TFs up to ten times higher than the average and conventional ones, even if always very low (Table A1).

2.2.2. Cash Flow Composition Variables

Investments subtract value from the cash flow, which makes negative the sign of the elasticity. The differences in elasticity depend on the size of *investments* on CAFFE: the greater their weight, the greater the sensitivity to their variation, as happens in the TFs with *medium sustainability* of both methods[8]. The weight of this variable on CAFFE is lower in organic farms than in conventional ones, which indicates that the former require greater availability of cash flow to activate their investments. This difference is essentially due to the large weight gap in *poor sustainability* cluster. On the other hand, the slope of the function is not different amongst TFs and production methods: its value (–0.91) indicates that a variation of investments is transmitted 90% to the cash flow of the year.

CAP I elasticity is higher for conventional TFs with *poor sustainability* and organic TFs with *medium sustainability*. The slopes of the function are similar (0.65), indicating that about 65% of the payment translates into CAFFE. Exceptions are *mixed crops and livestock* in organic farming, whose slope reaches 0.76 (Table A2)[9]. The high incidence of *CAP I* in the many *arable crop* farms in conventional and *olive growing* in organic, increases the elasticity of the clusters they belong (*poor sustainability* and *medium sustainability*). Conversely, the low incidence of *CAP I* in conventional *vineyard* reduces its elasticity. The weight of *CAP II* on CAFFE is also dominant in differencing reactivity, since the slope of the function is analogous in all TFs and with respect to *CAP I*. These payments concern specific measures for organic farming, and this increases the incidence and elasticity in these farms, especially in TFs with *medium* and *high sustainability*. Exceptions are *mixed crops and livestock* and *greenhouse vegetables,* where these payments are less relevant or completely absent in organic farms.

Organic farms also show a higher Δ*WCC* elasticity. The average figure reflects differences in value and sign of elasticity, with TFs where the relationship with the market leads to a liquidity loss and others with the

8. The case of organic *mixed livestock* is interesting because of the high elasticity due to higher investments in relation to CAFFE (Table A1).

9. In that case, the limited weight of CAP I on CAFFE keeps the elasticity value low (Table A3).

opposite result. The elasticity in the organic cluster with *poor sustainability* is positive and relatively high, for a favourable relationship with the market due to the high absolute value of the variable (not reported) and of its weight on CAFFE (Table A3). The conventional cluster with *high sustainability* shows a similar condition, mainly due to *intensive beef cattle*. All the other groups have a negative balance of the relationships with customers and suppliers. It is interesting to note that the slope of Δ*WCC* is greater than for *CAP I* and *CAP II*, that is the increase of this variable has a greater ability to generate CAFFE (Table A2). Furthermore, it should be noted that the average incidence of this variable on CAFFE in organic TFs is like that of *CAP II* (0.17 vs 0.15 - Tab. A3), while it reaches the levels of *CAP I* in the organic cluster with *poor sustainability* (0.26 vs 0.27 - Table A3).

2.2.3. Economic and productive results variables

ROI elasticity shows the influence of changes in efficiency: the variable is calculated net of CAP I payments. This subtraction makes negative the sign of *ROI* and of its elasticity; yet efficiency gains increase CAFFE, which requires assessing that elasticity based on its absolute value. In this sense, most of the TFs in the *poor sustainability* cluster have lower elasticity in organic than in conventional due to a smaller incidence of ROI on CAFFE (Table A3)[10]. In the other two clusters the situation is opposite and organic farms are more responsive than conventional to increases of efficiency. Most of the sensitivity of the *medium sustainability* cluster is due to the high inefficiency, consequently the high incidence of *ROI* on CAFFE, in organic *greenhouse vegetable*s (Table A3). The organic farms of the *high sustainability* cluster show more sensitivity to changes in efficiency, mainly for reactivity of *poultry, citrus fruits,* and *intensive beef cattle*.

The prices obtained and the yields achieved by most farms are lower than the average values of the areas in which they operate. This makes the losses of Gross Marketable Production (GMO) prevail and gives a negative sign to *price* and *yield advantages* elasticities. Even in these cases the slope of the function indicates that CAFFE grows as the *advantages* grow, that is, as *disadvantages* decrease. This requires evaluating the current situation based on the absolute value of those elasticities. *Price (dis)advantage* elasticity is lower in organic farms where the impact of GMO loss on CAFFE is lower than in conventional TFs. This is due to the condition of *medium* and *high sustainability* clusters. The organic cluster with *poor sustainability* has

10. The ratio of *ROI* over CAFFE in Table A3 is multiplied by 1,000,000 to better show the differences between the TFs.

instead a higher weight of *price (dis)advantage*, therefore, of the elasticity: this is mostly due to the large *price (dis)advantage* in the mixed TFs (Table A3)[11]. *Yield (dis)advantage* elasticity is the same for two methods. Greater differences are found in the organic TFs of the *high sustainability* cluster where, above all, in *other* and in *open field vegetables* the lower yields determine large losses of GMO in absolute value and in relation to CAFFE (Table A3). The slope of the function indicates that changing the *yield (dis) advantage* has a greater impact (0.20) than changing the *price (dis)advantage* (0.14); moreover, without differences between organic and conventional farms (Table A2).

3. Discussions

3.1. *General conditions of sustainability*

Organic farms represent 13.1% of the FADN sample analysed in this paper; their relevance is greater in some TFs, up to about 50% in *citrus* farms, and only a few TFs show a percentage value far from Italian agriculture real composition. The FCFE value indicates that organic farms generate more liquidity per unit of labour and compensate for capital depreciation more than conventional ones. This result find feedback in Mohamad *et al.* (2014) and in Brožová et Beranova (2017). Other authors obtain similar results comparing organic farms to conventional ones although, mainly, for economic profitability variables (Sgroi *et al.*, 2015a, 2015b; Acs *et al.*, 2007; Tudisca *et al.*, 2014; Hampl, 2020). Sorting the TFs of the two methods into three clusters allows a clear dichotomy to emerge. TFs with *poor sustainability* show good results only under organic farming. On the contrary, when engaged in the activities of this cluster, conventional farms generally fail to compensate for the depreciation of capital. In other words, in the segments of Italian agriculture that show greater difficulty in balancing capital depreciation with cash flow (62% of the FADN sample), farms that adopt the organic method are on average financially viable. The *high sustainability* cluster (19% of the FADN sample) is in the most favourable condition, and here the conventional farms obtain the best results. Organic farms are in a clear minority (11%) in this cluster and in some TFs do not compensate for the depreciation of the capital. This result confirms the findings of Pietola et Lansink (2001), i.e., that farms who require intensive processes, including labour, only convert to organic farming if they already have larger

11. Conversely, *open field vegetables* show a greater weight of this GMO loss on CAFFE, which makes *organic* farms more sensitive than *conventional* ones.

endowments of land, available only to a minority of farms. Furthermore, Pietola et Lansink (2001) and Bonfiglio et Arzeni (2019) highlight the impact of organic constraints and conclude that, because of them, farms in intensive sectors tend not to convert to this method. Also, Gillespie and Nehring (2013) affirm that organic cow-calf farms, *Intensive Beef Cattle* in this work, show higher fixed expenses and that they could only cover them by having greater returns than if the farm had been conventional. The *medium sustainability* cluster includes many TFs typical of Italian agriculture: here organic farms are more sustainable and generate more cash flow than conventional ones. This confirms the results of Sgroi *et al.* (2015a), Mohamad *et al.* (2014), Raimondo *et al.* (2021) about the *olive growing* sector, which in our study falls into this cluster.

3.2. *Influence of Factors Determining Elasticity*

These results can be associated with the elasticity values of the various TFs for: structural variables, variables composing the cash flow, and variables representing economic and productive results.

3.2.1. Influence of Structural Variables

Farms of both methods are more responsive to *farmland*, however, the reactivity in organic farms is lower, suggesting that those farms are closer to a better-balanced endowment than conventional. The gap is greater in *poor* and *medium sustainability* clusters, whose organic farms produce more CAFFE per unit of farmland than conventional farms. The opposite occurs in the *high sustainability* cluster, where policy constraints to organic farming require higher *farmland* endowments to produce CAFFE, and the high elasticity indicates that those farms are very sensitive to scale up. Organic farms also produce more CAFFE per *inventories* unit, which reduces the endowment of this capital compared to conventional farms. Especially in *highly sustainable* cluster, this makes organic farms less sensitive to this regressor, while conventional farms require greater stocks, also due to a greater number of cattle for the restock. The two regressors in the two production methods have similar function slope, indicating that 10% of a *farmland* endowment variation is transferred in producing CAFFE, while 40% is transferred for *inventories* variation.

Some analysis on the impact of various assets endowment on efficiency come to diverse conclusions. According to Madau (2007) land in arable farms has a greater impact in organic than in conventional. Cisilino et Madau

(2007) examine all organic farms in the FADN network and come to similar conclusions on the greater importance of scale in organic compared to conventional farms. According to Flubacher *et al.* (2015), the most important factors in organic dairy farms are costs and depreciable capital endowments. Gillespie *et al.* (2008) agree on the relevance of production size and its growth for organic dairy farms, which, in our sample, have greater *farmland* and *inventories* elasticities than the conventional ones.

Finally, the low elasticity of *depreciable* is due to the negligible slope of the function and not to its weight on CAFFE, which, indeed, is greater than the relevance of *inventories*. In other words, while assuming an appreciable weight over FCFE, these investments fail to increase CAFFE. In accordance with the conclusions of Dono *et al.* (2021) and Pingali (2012) it can be assumed that even organic farms find it difficult to take full advantage of the new technologies, most IoT, embedded in the most innovative and expensive capital. Raimondo *et al.* (2021) come to a different conclusion attributing considerable importance to the depreciable capital equipment for the technical efficiency of organic *olive growing* farms. These farms are among the most equipped with these capitals in our study as well, although less than in conventional and always with low levels of elasticity compared to them. Ultimately, our study shows that organic farms generate much more cash flows from the use of these three types of capital than conventional ones do. It should also be said, however, that organic farms are more endowed with these types of capital than conventional farms; and that this is especially true in the *poor and medium sustainability* clusters.

3.2.2. Influence of the variables that contribute to compose the cash flow

CAFFE's responsiveness to *investments* is generally low, and in conventional TFs it is higher than in organic TFs: thus, the latter invest a smaller portion of the generated liquidity or, conversely, require more liquidity to generate the same amount of investment. This is true in the cluster with *poor* and *medium sustainability*, while in *high sustainability* cluster it is the opposite and organic farms show a greater propensity to invest CAFFE. Finally, *investments* subtract 91% of their amount, i.e., 9% of their value returns to CAFFE. This raises the question of how much these cash flow returns are due to productivity gains related to the renewal or expansion of capital endowments or simply to the refunds of public support, which, moreover, with the RDP measures returns more than 9%, even if not to all farms.

CAP I and *CAP II* payments have a different impact and weight on organic and conventional farms. The slope of the function, i.e., the part of the payments that converts to CAFFE and, conversely, the farm costs of the policy, is similar in the two methods. This suggests that organic farms do not cope more easily with the payments conditionality, suffering appreciable burdens even to fulfil the green or environmental commitments of the policy[12]. Krause et Spicka (2017) note that organic farms are more dependent on payments; Lakner et Breustedt (2017) also highlight their great influence over production decisions. Sgroi *et al.* (2015b), Brožová et Beranova (2017) and Mohamad *et al.* (2014) conclude that, on equal terms, the financial situation of organic farms could get much worse without the liquidity contribution of public payments. They estimate that the price of their products, which is already higher, would have to increase by 35% to compensate for the subtraction. Our analysis shows that payments are higher for organic farms but in average result in higher liquidity, mostly in the clusters with *poor* and *high sustainability*. On the other hand, the relevance of *CAP I* and *CAP II* on CAFFE is different fort the two methods: the former affects more conventional farms; the latter includes specific aids for organic farms and affects more their CAFFE generation.

A significant difference between organic and conventional farms concerns the impact of Δ*WCC*. The balance of market relationships with customers and suppliers increases the liquidity of organic farms that are more sensible to its variation. This is especially true for the cluster with *poor sustainability* where the weight Δ*WCC* on CAFFE is 0.26, versus 0.27 of CAP I and 0.11 of CAP II. On the other hand, the Δ*WCC* elasticity in this cluster is even greater than *CAP I* and *CAP II* ones, indicating that for this group of TFs, and especially for the mixed typologies, improving the balance of relationships with customers and suppliers increases liquidity more than an analogous increase in those public aid. This balance indicates the willingness of the system to grant credit to organic farms, immediately paying for the purchased goods and willing to wait longer for the balance of the production factors' bills. The similarity between the advantage constituted by this credit and that due to public payments suggests that it may be interesting to investigate the joint effect of these variables. In other words, to evaluate how much the credit granted to the sector is due to the climate of confidence in it, and how much it is related to the injection of liquidity that is attributed to public support.

3.2.3. Influence of economic and productive results variables

Organic farms are less efficient than the others, but they are also less responsive to a change in *ROI*, given its lower incidence in determining

12. *Mixed crops and livestock* are a relevant exception with lower costs for policy conditionalities in organic farming.

the value of CAFFE. This mainly reflects the condition of mixed TFs. In contrast, in the *high sustainability* cluster, *ROI* affects CAFFE more, which makes organic farms relatively more sensitive to changes in efficiency[13]. Ultimately, a cluster-level comparison does not reveal a specularity between the responsiveness to changes in *ROI* and to changes in *CAP I* and *CAP II* aid. In other words, there is no indication that lesser (greater) reactivity to changes in *ROI* is accompanied by greater (lesser) reactivity to public aid.

For the great part of farms, and their production GMO, losses prevail due to lower-than-average prices and yields. Organic farms were expected to obtain product yields lower than the arithmetic average of the areas in which they operate. It was less obvious that even a prominent part in organic production receives prices below the average of the areas in which farms operate, an average which includes the conventional prices. Still, the greater CAFFE production of organic farms mitigates the impact of the GMOs loss compared to conventional farms and also reduces the *price (dis) advantage* elasticity. However, the impact increases in organic cluster with *high sustainability* due to the higher weight of this (dis)advantage. The same applies to the *yield (dis)advantage*, whose responsiveness increases in the same cluster. Finally, the slopes of the function indicate that, for both organic and conventional farms, it is cheaper to increase CAFFE by reducing the GMO loss due to the yield disadvantage than to operate to reduce the loss due to the price disadvantage.

About price conditions, Acs *et al*. (2009) underline that the prices of organic products are more volatile than conventional ones because the substitutability of organic products with the former is greater than the opposite. Therefore, the policy support to convert should be higher to cover the market risk. Pietola and Lansink (2001) highlight the key role of prices and yields and policy support both in the decision to convert to organic and in the economic and financial performance of organic farms. Many authors stress the relevance of the combination of these three factors, where the higher prices obtained by organic products in the market should compensate for the lower yields (Sgroi *et al*., 2015a, 2015b; Flubacher *et al*., 2015; Acs *et al*., 2007; Mohamad *et al*., 2014; Tudisca *et al*., 2014; Pimentel *et al*., 2005; Offerman and Nieberg, 2000). Various authors claim that this is not always the case, especially for livestock products and some vegetables, as well as under specific soil conditions (Seufert *et al*., 2012; Krause et Spicka, 2017; Berentsen *et al*., 2012; Hafla *et al*., 2013 Krause et Machek, 2017). Finally, Abele *et al*. (2007) and Bennett and Franzel (2013) point out that the benefits of selling organic products largely go to traders and middlemen and

13. Interestingly *poultry* farms are more efficient and responsive under organic than in conventional.

not to farmers. Our results seem to support the latter conclusion when they highlight that, even in the organic cluster with highly sustainable TF, there is a significant price disadvantage. In other words, most organic farms receive prices for their products that are lower than the average for the geographic areas in which they operate.

4. Conclusions

The analysis shows that financial sustainability is, on average, greater for organic than conventional TFs, and in several cases the level reached by the former is very high. This applies to all clusters analysed. An interesting result concerns the cluster defined as *poor sustainability* based on the general situation of its TFs in our sample. Most of the conventional TFs, which represent an important part of the farms in our sample, are far from the financial sustainability condition that we are considering, while the organic TFs achieve it, even with large margins. Approaching to organic farming can thus increase the financial sustainability of many farms that operate in this cluster and that have more difficulty in adopting the specialization and technological adaptation solutions of the so-called *agriculture 4.0*. The organic conduction also prevails in the *medium sustainability* cluster, while conventional farms are barely sustainable. Finally, organic farming is largely sustainable in the *high sustainability* cluster, even if the result of conventional farms is better.

Organic farms produce more cash flow than conventional farms with the same endowment of various capitals, which reduces their relative elasticity. The growth of *farmland* endowment has major effects; still, it is evident that these are of greater importance in conventional than organic farms. This suggests that the structural endowment is more balanced in organic farming activities, and the need to increase the operational size for better financial results is less than in conventional farms. An exception is the highly sustainable cluster, where the *farmland* endowment influences the liquidity production more in organic than in conventional farms. This aspect is worthy of further study, as the small size of the farms still considerably limits the results of Italian agriculture, and organic farms seem less bounded by this constraint. These works should use other functional forms to represent the studied relationships, as well as examine the condition of the size classes that make up the various aggregates.

A major part of the sustainability of organic farms is certainly due to EU payments, mainly of CAP II type. Payments are, in fact, relatively higher for the organic TFs and result in higher liquidity especially in mixed organic farms (*poor sustainability* cluster). The result is not the same in terms of generated liquidity in *medium* and *high sustainability* clusters, which are more sensitive to these payments. This could suggest that relying on this aid could reduce the responsiveness of organic farms to changes in efficiency (Lakner, 2009), which is lower than in conventional farms when measured as ROI elasticity. Still, we found no evidence that greater sensitivity to public aid is accompanied by less responsiveness to changes in efficiency. This problem certainly requires further investigation, maybe to calibrate the supports to the sector differently.

Another strong point of organic farms lies in the relationships with customers and suppliers which allows to increase CAFFE almost as much as the total amount of public aid received, especially in the *poor sustainability* cluster. The benefit generated by this credit is contextual and of a similar level to public payments. It is interesting to investigate how the climate of trust and market appreciation and the security of solvency due to the liquidity injection provided by public aid interact in generating this credit. Obviously, if the good reputation of the sector has these tangible and positive effects on cash flows, all efforts must be dedicated to its preservation, guaranteeing the factors that generate it. Still, this does not change the volatility of the variable since the additional liquidity comes from ΔWCC and not from its absolute level. In other words, this variable has a positive effect only if the balance of willingness to credit by customers and suppliers grows progressively. This makes it of interest to evaluate how to increase, as well as how to best capture this appreciation. In this regard, it could be studied how to develop forms of participation in investments and in the productive activities of the organic sector, such as *crowdfunding*. This can add important financial resources to support investments which, as our analysis has highlighted, are undertaken by organic farms only with higher liquidity levels than those required by conventional farms.

These results could be supported by efforts to improve pricing and yield conditions, as much of the GMO is achieved with below-average results for both variables. The existence of an appreciable *price disadvantage* contradicts the widespread opinion that all organic farms get higher prices for their products. Our result shows that this ability is prerogative of a minority of producers, whose relevance in the production is even less than what happens for conventional farms. Moreover, our analysis indicates that reducing this gap might also be very expensive to increase cash flows for a wide range of farms, both organic and conventional. In fact, despite in some cases the large disadvantages for prices or yields, the elasticity remains low except for the organic TFs of the highly sustainable cluster, whose yield disadvantage is enormous compared to the territorial and altimetric averages.

Our analytical approach can be used by Countries using the FADN, or similar sampling systems on accounting data, to assess the situation of their agriculture and help specify policy measures. In this regard, it would be useful to refine the representativeness of the FADN sample by extending it to better cover the farms in conversion. The analysis carried out highlights that the level of financial sustainability of the small group of farms operating at this stage is insufficient. However, the number of observations examined is too limited to support these conclusions or to satisfactorily assess the problems that arise at this stage, which is crucial to gain access to the organic method.

At last, the remarks on sustainability resulting from the analysis should be considered precautionary: in fact, calculating the depreciation on the current replacement value of capital, while providing a stronger signal on the sustainability of those systems, could reveal a more precarious situation for many areas, given the age of the capital of many Italian farms. Our analysis can be further deepened by considering altitude level and geographical areas, as well as productive dimension and engagement in direct selling, food processing and farm holidays, which can provide useful hints.

Acknowledgement

This research was carried out in the context of two projects funded by MIUR (MInistry for Education, University and Research): Department of Excellence project (law 232/2016) and SMARTIES project (PRIMA 2019, section 2 – multi-topic). The funders had no role in the study design, data collection and analysis, decision to publish or manuscript preparation.

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Table A1 - Variable elasticities in each TF and cluster of TFs for Organic (O) and Conventional (C) farms

	Farmland		Inventories		Depreciable		Investments		CAP I		CAP II		ΔWCC		ROI		Price Advantage		Yield advantage	
	O	C	O	C	O	C	O	C	O	C	O	C	O	C	O	C	O	C	O	C
Mixed Crops and Livestock	0.36	1.37	0.15	0.59	0.003	0.005	-0.05	-0.62	0.12	0.33	0.01	0.07	0.33	0.07	-0.00	-0.49	-0.08	-0.04	-0.01	0.02
Extensive Beef Cattle	0.63	0.68	0.30	0.58	0.001	0.002	-0.25	-0.34	0.31	0.29	0.20	0.10	0.00	0.02	-0.25	-0.48	-0.09	0.04	-0.03	-0.01
Mixed Crops	0.80	1.42	0.05	0.15	0.004	0.003	-0.56	-0.35	0.19	0.25	0.12	0.06	0.24	-0.08	-0.44	-0.62	-0.20	-0.12	-0.02	-0.09
Mixed Fruits	0.78	1.12	0.03	0.03	0.001	0.002	-0.12	-0.49	0.18	0.08	0.11	0.02	0.00	0.02	-0.23	-0.16	-0.04	-0.06	-0.02	0.03
Arable Crops	0.90	1.71	0.09	0.16	0.003	0.005	-0.35	-0.58	0.29	0.50	0.12	0.08	0.13	0.05	-0.14	-0.48	-0.01	-0.07	-0.03	-0.04
Sheep	0.79	0.57	0.15	0.16	0.002	0.002	-0.29	-0.28	0.25	0.18	0.20	0.11	0.00	-0.01	-0.11	-0.18	-0.02	0.00	-0.01	0.00
Dairy Cattle	0.86	0.59	0.51	0.29	0.020	0.006	-0.76	-0.47	0.18	0.12	0.31	0.07	-0.08	0.02	-0.02	-0.02	-0.02	-0.03	-0.06	0.01
Vineyards	0.52	1.02	0.19	0.35	0.002	0.001	-0.27	-0.38	0.09	0.05	0.06	0.04	0.00	-0.05	-0.02	-0.15	-0.01	-0.03	-0.03	-0.03
Mixed Livestock	2.26	0.73	0.98	0.68	0.001	0.003	-5.63	-0.68	0.61	0.23	0.66	0.10	0.14	-0.06	-0.04	-0.54	-0.01	-0.09	0.17	-0.02
Greenhouses Vegetables	0.06	0.24	0.00	0.15	0.015	0.002	-0.11	-0.22	0.00	0.01	0.00	0.02	0.02	0.03	-0.34	-0.08	0.01	-0.05	0.21	0.20
Olive Growing	1.04	1.83	0.13	0.16	0.003	0.004	-0.22	-1.03	0.42	0.86	0.20	0.06	-0.02	0.10	-0.56	-0.91	-0.01	-0.01	-0.03	-0.14
Swine	0.13	0.54	-	1.24	0.000	0.008	-0.02	-0.19	0.02	0.08	0.01	0.01	0.03	-0.24	0.05	-0.02	0.01	-0.57	-0.03	0.00
Other	0.52	0.37	0.31	0.16	0.001	0.001	-0.23	-0.18	0.04	0.01	0.07	0.02	-0.05	-0.03	-0.09	-0.12	0.07	-0.38	-1.83	-0.79
Poultry	0.38	0.22	0.23	0.21	0.003	0.004	-0.68	-0.10	0.06	0.03	0.05	0.01	0.07	0.01	0.23	0.08	-0.01	-0.11	-0.01	0.00
Citrus Fruits	0.59	0.76	0.01	0.02	0.000	0.001	-0.03	-0.10	0.19	0.16	0.16	0.02	-0.07	0.10	-0.29	-0.31	-0.06	-0.03	-0.02	0.00
Open Field Vegetables	1.17	0.38	0.15	0.02	0.004	0.001	-0.23	-0.11	0.16	0.12	0.19	0.02	-0.10	0.00	0.00	-0.09	-0.37	-0.22	-0.52	-0.02
Fruits in Shell	0.42	0.22	-	0.03	0.001	0.001	-0.26	-0.22	0.04	0.08	0.06	0.06	0.01	0.01	0.02	0.10	0.00	0.06	-0.04	-0.02
Intensive Beef Cattle	2.72	0.31	0.47	0.83	0.002	0.001	-0.26	-0.13	0.38	0.33	0.36	0.01	0.05	0.16	-0.21	-0.05	0.14	0.03	-0.07	0.00
Poor sustainability	0.72	1.19	0.14	0.21	0.002	0.004	-0.19	-0.49	0.17	0.29	0.08	0.07	0.19	0.02	-0.11	-0.32	-0.07	-0.05	0.72	1.19
Medium sustainability	0.81	1.01	0.18	0.33	0.003	0.002	-0.42	-0.44	0.26	0.12	0.14	0.05	0.00	-0.03	-0.30	-0.23	-0.01	-0.04	0.81	1.01
High sustainability	0.71	0.37	0.09	0.42	0.001	0.002	-0.16	-0.14	0.14	0.11	0.14	0.02	-0.05	0.00	-0.15	-0.05	-0.08	-0.23	0.71	0.37
Total	0.74	0.88	0.14	0.30	0.002	0.003	- 0.23	- 0.36	0.19	0.20	0.10	0.05	0.12	0.01	- 0.15	- 0.21	- 0.06	- 0.11	- 0.06	- 0.06

Table A2 - Slope of the function for every TF and cluster of TFs for Organic (O) and Conventional (C) farms

	Farmland		Inventories		Depreciable		Investments		CAP I		CAP II		ΔWCC		ROI		Price Advantage		Yield advantage	
	O	**C**	**O**	**C**	**O**	**C**	**O**	**C**	**O**	**C**	**O**	**C**	**O**	**C**	**O**	**C**	**O**	**C**	**O**	**C**
Mixed Crops-Livestock	0.05	0.10	0.39	0.42	0.007	0.001	-0.91	-0.91	0.76	0.64	0.64	0.63	0.73	0.72	163,1	161,9	0.12	0.14	0.20	0.20
Extensive Beef Cattle	0.10	0.10	0.42	0.42	0.001	0.001	-0.90	-0.90	0.65	0.64	0.65	0.63	0.72	0.72	162,0	161,8	0.14	0.14	0.20	0.20
Mixed Crops	0.09	0.09	0.43	0.43	0.002	0.001	-0.91	-0.90	0.64	0.64	0.64	0.63	0.72	0.72	160,4	160,8	0.14	0.14	0.20	0.20
Mixed Fruits	0.09	0.10	0.43	0.43	0.001	0.001	-0.90	-0.91	0.64	0.63	0.64	0.63	0.72	0.72	161,8	162,7	0.14	0.14	0.20	0.20
Arable Crops	0.09	0.09	0.43	0.43	0.002	0.002	-0.91	-0.91	0.66	0.65	0.65	0.63	0.72	0.72	162,1	161,2	0.14	0.14	0.20	0.20
Sheep	0.10	0.10	0.43	0.43	0.001	0.001	-0.91	-0.90	0.64	0.64	0.65	0.63	0.72	0.72	162,8	162,5	0.14	0.14	0.20	0.20
Dairy Cattle	0.10	0.10	0.42	0.42	0.003	0.002	-0.91	-0.91	0.64	0.64	0.65	0.63	0.72	0.72	163,3	163,3	0.14	0.14	0.20	0.20
Vineyards	0.09	0.09	0.42	0.42	0.002	0.001	-0.91	-0.91	0.64	0.63	0.64	0.63	0.72	0.72	163,2	162,7	0.14	0.14	0.20	0.20
Mixed Livestock	0.09	0.10	0.42	0.42	0.001	0.001	-0.91	-0.90	0.65	0.63	0.67	0.63	0.72	0.72	163,3	162,1	0.14	0.14	0.20	0.20
Greenhouses Vegetables	0.10	0.10	0.43	0.43	0.005	0.001	-0.90	-0.90	0.63	0.63	0.62	0.63	0.72	0.72	157,8	162,8	0.14	0.14	0.20	0.20
Olive Growing	0.09	0.09	0.43	0.43	0.002	0.001	-0.90	-0.91	0.66	0.66	0.65	0.63	0.72	0.72	159,4	160,4	0.14	0.14	0.20	0.20
Swine	0.10	0.09	0.43	0.39	0.000	0.004	-0.90	-0.91	0.63	0.64	0.63	0.63	0.72	0.72	163,7	163,2	0.14	0.13	0.20	0.20
Other	0.10	0.10	0.42	0.43	0.001	0.001	-0.90	-0.90	0.63	0.63	0.63	0.63	0.72	0.72	162,8	162,8	0.14	0.14	0.18	0.19
Poultry	0.10	0.10	0.43	0.42	0.001	0.003	-0.91	-0.90	0.63	0.63	0.63	0.63	0.72	0.72	164,4	164,4	0.14	0.14	0.20	0.20
Citrus Fruits	0.09	0.10	0.43	0.43	0.001	0.001	-0.90	-0.90	0.65	0.64	0.66	0.63	0.72	0.72	160,4	161,6	0.14	0.14	0.20	0.20
Open Field Vegetables	0.09	0.10	0.42	0.43	0.002	0.001	-0.91	-0.90	0.64	0.64	0.65	0.63	0.72	0.72	163,4	162,5	0.14	0.14	0.19	0.20
Fruits in Shell	0.09	0.10	0.43	0.43	0.001	0.001	-0.91	-0.91	0.63	0.64	0.64	0.63	0.72	0.72	163,7	164,4	0.14	0.14	0.20	0.20
Intensive Beef Cattle	0.09	0.09	0.42	0.39	0.001	0.002	-0.90	-0.91	0.65	0.69	0.66	0.63	0.72	0.72	162,4	162,3	0.14	0.14	0.20	0.20
Poor sustainability	0.09	0.09	0.42	0.43	0.002	0.001	-0.91	-0.91	0.65	0.64	0.64	0.63	0.72	0.72	162.0	161.9	0.14	0.14	0.20	0.20
Medium sustainability	0.09	0.10	0.42	0.42	0.002	0.001	-0.91	-0.91	0.65	0.63	0.65	0.63	0.72	0.72	160.9	162.3	0.14	0.14	0.20	0.20
High sustainability	0.09	0.10	0.43	0.42	0.001	0.001	-0.90	-0.90	0.64	0.64	0.65	0.63	0.72	0.72	162.1	162.9	0.14	0.14	0.20	0.20
Total	0.09	0.10	0.42	0.42	0.002	0.001	-0.91	-0.91	0.65	0.64	0.65	0.63	0.72	0.72	161.8	162.2	0.14	0.14	0.20	0.20

Table A3 - Average value of each regressor divided by CAFFE value for each TF and cluster of TFs for Organic (O) and Conventional (C) farms

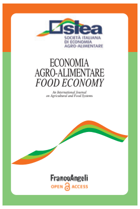
	Farmland		Inventories		Depreciable		Investments		CAP I		CAP II		ΔWCC		ROI$_{14}$		Price Advantage		Yield advantage	
	O	C	O	C	O	C	O	C	O	C	O	C	O	C	O	C	O	C	O	C
Mixed Crops and Livestock	6.94	14.39	0.39	1.39	0.5	3.4	0.05	0.69	0.16	0.51	0.01	0.12	0.45	0.10	-0.02	-3.01	-0.66	-0.25	-0.07	0.10
Extensive Beef Cattle	6.56	7.07	0.70	1.37	1.0	2.1	0.28	0.38	0.47	0.46	0.31	0.16	-0.01	0.03	-1.54	-2.97	-0.61	0.27	-0.16	-0.05
Mixed Crops	8.48	15.08	0.11	0.36	2.1	2.4	0.62	0.39	0.30	0.39	0.18	0.09	0.33	-0.11	-2.76	-3.85	-1.40	-0.88	-0.11	-0.43
Mixed Fruits	8.28	11.83	0.07	0.08	1.1	1.9	0.14	0.54	0.27	0.12	0.17	0.04	0.00	0.03	-1.45	-0.96	-0.27	-0.42	-0.12	0.17
Arable Crops	9.70	18.26	0.22	0.37	1.5	3.0	0.38	0.64	0.44	0.77	0.19	0.13	0.18	0.07	-0.83	-3.01	-0.08	-0.52	-0.16	-0.19
Sheep	8.31	5.94	0.36	0.38	1.4	1.7	0.32	0.31	0.39	0.29	0.31	0.17	0.00	-0.01	-0.66	-1.13	-0.14	0.01	-0.06	0.01
Dairy Cattle	9.01	6.20	1.21	0.67	6.2	2.6	0.84	0.52	0.29	0.19	0.47	0.11	-0.11	0.03	-0.12	-0.10	-0.13	-0.22	-0.32	0.07
Vineyards	5.45	10.76	0.45	0.81	1.2	1.5	0.30	0.42	0.14	0.08	0.09	0.07	0.00	-0.07	-0.12	-0.91	-0.04	-0.22	-0.15	-0.16
Mixed Livestock	24.41	7.57	2.33	1.60	1.4	3.0	6.18	0.75	0.94	0.36	0.98	0.16	0.19	-0.08	-0.24	-3.36	-0.04	-0.64	0.82	-0.12
Greenhouses Vegetables	0.64	2.47	0.01	0.36	2.7	1.4	0.12	0.24	0.00	0.01	0.00	0.03	0.02	0.04	-2.14	-0.51	0.08	-0.37	1.02	0.97
Olive Growing	11.05	19.33	0.31	0.36	1.9	3.0	0.24	1.14	0.64	1.31	0.31	0.09	-0.02	0.13	-3.52	-5.70	-0.10	-0.08	-0.16	-0.70
Swine	1.28	5.70	-	3.14	0.3	2.2	0.02	0.21	0.03	0.13	0.02	0.01	0.05	-0.33	0.31	-0.11	0.07	-4.55	-0.13	0.01
Other	5.43	3.79	0.72	0.38	1.0	1.0	0.25	0.20	0.07	0.02	0.11	0.03	-0.07	-0.04	-0.58	-0.72	0.50	-2.74	-10.04	-4.06
Poultry	3.87	2.32	0.55	0.49	2.3	1.7	0.75	0.11	0.10	0.04	0.08	0.02	0.10	0.01	1.37	0.51	-0.05	-0.75	-0.06	0.00
Citrus Fruits	6.28	7.95	0.02	0.05	0.5	1.2	0.04	0.11	0.29	0.24	0.25	0.03	-0.09	0.14	-1.80	-1.95	-0.46	-0.20	-0.10	0.00
Open Field Vegetables	12.62	3.97	0.36	0.06	2.0	0.9	0.26	0.12	0.25	0.18	0.29	0.03	-0.14	0.00	0.01	-0.54	-2.71	-1.63	-2.67	-0.08
Fruits in Shell	4.51	2.32	-	0.06	0.5	0.8	0.29	0.24	0.06	0.12	0.09	0.09	0.02	0.01	0.09	0.59	0.02	0.40	-0.19	-0.08
Intensive Beef Cattle	29.97	3.26	1.12	2.13	1.8	0.6	0.29	0.14	0.59	0.47	0.54	0.02	0.07	0.22	-1.31	-0.33	1.01	0.18	-0.35	0.00
Poor sustainability	7.79	12.52	0.34	0.50	1.1	2.5	0.21	0.54	0.27	0.45	0.12	0.11	0.26	0.03	-0.66	-1.98	-0.51	-0.36	-0.10	-0.06
Medium sustainability	8.61	10.56	0.43	0.79	1.6	1.7	0.46	0.48	0.40	0.19	0.22	0.07	0.00	-0.04	-1.84	-1.44	-0.06	-0.25	-0.08	-0.11
High sustainability	7.53	3.82	0.21	1.01	1.0	1.2	0.17	0.15	0.22	0.18	0.21	0.03	-0.07	0.00	-0.91	-0.30	-0.59	-1.64	-1.81	-0.76
Total	7.91	9.26	0.34	0.71	1.1	1.9	0.25	0.40	0.29	0.32	0.15	0.08	0.17	0.01	-0.92	-1.33	-0.44	-0.78	-0.32	-0.31

1. The ratio of ROI over CAFFE is multiplied by 1,000,000.

Economia agro-alimentare /
Food Economy

An International Journal on Agricultural and Food Systems

Vol. 23, Iss. 3, Art. 12, pp. 1-22 - ISSN 1126-1668 - ISSNe 1972-4802
DOI: 10.3280/ecag3-oa12767



Sustainability and competitiveness in farms: An evidence of Lazio region agriculture through FADN data analysis

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Abstract

The new legislative proposals related to the Common Agricultural Policy (CAP) reform 2021-2027 aim to promote a sustainable and competitive agricultural sector. The new CAP supports agriculture in making a much stronger contribution to climate, biodiversity, environment and improving farms' competitiveness in the agri-food sector, in a European context. The importance of a strong focus on results and performance in the CAP legislation requires a continuous assessment and monitoring of the effectiveness of the measures adopted in the Rural Development Programs (RDP) with respect to the specific goals set during the CAP program. In order to assess the progress in improving the competitiveness and sustainability of the agri-food sector in reaching their targets and the objectives of the CAP, the need arises to investigate whether the RDP measures contribute to supporting the transition towards sustainable agriculture, to the competitiveness of the agri-food sector and to a balanced development of the rural areas. In this new legislative framework, where it becomes important to evaluate whether the CAP provides a much stronger contribution to achieving the specific objectives, our paper aims to describe agricultural sector in the Lazio region and to analyze the effects, in terms of sustainability and competitiveness, of the measures approved by RDP 2014-2020, which have almost expired. In particular, we

Article info

Type:
Article
Submitted:
14/05/2021
Accepted:
20/09/2021
Available online:
12/01/2022

JEL codes:
Q18, R58, R11

Keywords:
Rural development
FADN
Sustainable Development
Agricultural economics
Environment

Managing Editor:
Lucia Briamonte,
Luca Cesaro,
Alfonso Scardera

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provide a comparative analysis of the data collected by the Farm Accountancy Data Network (FADN), focusing on two different periods: one prior to the last programming and one referring to the latest available data. The collected data refer to farms, regarding their structural, economic, financial and patrimonial characteristics, as well as variables that describe attitudes and behaviour towards the environment. A multivariate analysis (clustering) is applied; it focuses on explorative factor analysis based on principal components, in order to identify homogeneous groups of farms with sustainability and competitiveness and identify similar characteristics and potential for development trajectories. The results found that farms are moving towards more sustainable and multifunctional development paths. The assessment of EU goals for social, environmental, and economic sustainability in agriculture and rural areas are a basis for discussion among public decision-makers involved in the reforming process of the explanatory measures of the new strategic objectives of the post-2020 CAP. Our results can offer a contribution to meeting the current challenges posed by the EU to ensure a smooth transition to the future CAP program. Major challenges that raise policy debate on the considerable potential of the FADN for assessing sustainability and farm competitiveness in the EU framework which places strong emphasis on results and performance.

Introduction

In recent years, the environmental damage due to impact of agro-industrial production led to farms to adopt sustainable production patterns and at the same time, environmental awareness is growing in consumer's behaviour. The widespread use of new green technologies and consumer's awareness on environmental problems caused by high amount of waste produced by the agro-food industry, encouraged the development of a sustainable consumption models (Meulenberg, 2003), in order to mitigate the environmental impact of food production. In this context, the farms competitiveness cannot disregard to the adoption of a sustainable production model. In fact, the two concepts seem to be closely interrelated in a multifunctional agriculture perspective (Toth, 2012).

However, the CAP 2014-2020 programme support sustainability and competitiveness goals, as well as provide new development opportunities related to increased consumers interest for sustainable food products. In 2017, a public consultation was also launched by the European Commission on the CAP Future. The Commission has presented a Communication to the European Parliament [COM (2017) 713] with new legislative proposals [COM (2018) 0392, 0393 and 0394 of the 1 June 2018] for the CAP 2021-2027 reform, to discuss environmental issues and farms competitiveness. The Commission included three general objectives in its reform strategy, including "to bolster environmental care and climate action and to contribute to the environmental and climate objectives of the EU" and nine strategic goals focused on social, environmental and economic factors, including "enhance market orientation and increase competitiveness including greater focus on research, technology and digitalisation" and "foster sustainable development and efficient management of natural resources such as water, soil and air" (European Commission, 2018:12). Appears clear how the CAP draft reform post 2020 aims to combine environment and competitiveness in a single goal: the sustainability. This goal highlights how multifunctional agriculture remains the key to a more balanced and sustainable CAP capable of tackling new challenges related to climate change and biodiversity, to improving competitiveness, to promoting generational turn-over, the knowledge transfers and access of young farmers to the land; measures that contribute to strength the position of farmers in the supply chain. In this new legislative framework, the CAP will adapt better to the transition to sustainable production patterns, to strength the agri-food sector competitiveness. Despite the post-2020 CAP reform strategy confirm the implementation of actions that enhance the sustainability and farm competitiveness that exalting multifunctionality in agriculture, it becomes important to investigate the measures effectiveness of RDP in terms of competitiveness, sustainable management of natural resources and the balanced development of rural areas. In view of the considerations, this paper aims to provide a representation of farms of the Lazio region and to discuss if RDP 2014-2020 supported improving sustainability and competitiveness of regional agri-food sector. As suggested by the recent scientific literature, the goal of the transition towards a fully sustainable agricultural sector is one of the main factors that influence the emergence of a new dimension of farms competitiveness (Farah *et al.*, 2014; Aceleanu, 2016). The new evaluation framework suggested by CAP reform post 2020 rises the need for explanatory databases, both of economic performance and sustainability, capable of measuring the effectiveness of CAP measures at farm level. Our paper attempts to explore the relationship between competitiveness and sustainability in farms through the use of a FADN data set, contributing to the current debate. In particular, the decision to use the FADN database is suggested by existing literature that examines its effectiveness in the evaluation of EU programs (Kelly *et al.*, 2018). Our paper aims to reinforce the idea that the FADN database has considerable potential to evaluate the sustainability and competitiveness at farm level. For this purpose, we have collected explanatory data of the structural characteristics and farms sustainable behaviour organized over two distinct periods (2011-2019) and we proposed factorial analysis focus on the principal components. In order to offer a better interpretation of emerging farms profiles, they are sorted into homogeneous groups defined by a multivariate analysis (clustering), where we associated the possible development path of the farms. The results highlight the important contribution that the FADN can provide in evaluating of European programs effectiveness increasingly focused to ambitious levels of competitiveness and sustainability. This manuscript is organized in 4 sections: the first, discusses the relationship between competitiveness and environmental sustainability through the FADN data, while section 2 argues the methods and material; in section 3 the research results and discussions are represented and, finally, in section 4 the conclusions and future research design are reported.

1. Background

1.1. *A literature review on FADN data contribution in the policy assessment*

In recent years, the globalization of production and consumption increasingly require to promote long-term sustainable interventions within the society. As a result, concerns regarding the sustainability of agriculture are becoming increasingly important to policy makers (Bockstaller *et al*., 2009) and raises several questions about the discussions of decision-makers, including agricultural entrepreneurs, economists, managers and policy makers (Vitunskienė & Dabkienė, 2014; Vitunskienė *et al*., 2016). The RDP of Member States EU supports actions that favour the sustainability of agricultural products. The sustainable agriculture model gained relevance from the publication of the Brundtland Report in 1987 (Tait & Morris, 2000). In Our Common Future (World Commission, 1987: 6). according to which it is "development that meets the needs of the present without compromising the ability of future generations to meet their own needs". Subsequently, together with the fundamental concept of sustainable development, different definitions of sustainability were developed. In 2002, during the World Summit on Sustainable Development in Johannesburg, an unambiguous definition of sustainable development was agreed: sustainable development is considered a dynamic concept applicable at the farm level and at the decision-making farm level. This definition provides a broad interpretation of sustainable development understood as a dynamic balance between three interconnected dimensions. According to Diazabakana *et al.* (2014), these three dimensions are known as the sustainability pillar, thus sustainable development combines economic (the production of goods and services), environmental (the management of natural resources) and social sustainability (the contribution to rural dynamics). Integration of economic, social, and environmental dimensions is crucial to achieving sustainable development (United Nation, 2015). In 2007 Pingault defines sustainable development from an economic point of view as preserving or enlarging capital stock in the form of economic, social and natural capital. The proposal reform discussed by the European Commission on the CAP post 2020 confirm the priority objective of promoting a sustainable and competitive agricultural sector. From a sustainability perspective, the existence of multifunctional agriculture that provide a public goods and positive externalities justifies government intervention in a market economy through agricultural and sectoral policies (Dos Santos, 2016; 2018). In fact, in CAP programme 2014-2020 the actions aimed at improving the agriculture competitiveness and the sustainability were included in the six priorities of the national RDP and, despite the rationale of the implementation model of the new CAP is very different, the farms competitiveness and sustainability remain one of the long-term strategic goals for the post-2020 CAP. To achieve these objectives, each EU Member State will develop its own strategic plan, indicating how CAP funding will be directed towards specific objectives and how financial resources will contribute to the overall EU objectives. Programmes are country-specific because there are several endogenous and exogenous factors that influence the economic performance and farms competitiveness (Coppola *et al.*, 2018). While the objectives to achieve a multifunctional agriculture model are now clear, the post-2020 CAP reform and society's expectations of agriculture have increased the need for information on the policy effectiveness in achieving ambitious targets in the use of sustainable agricultural practices. Recent research shows the importance of studying the impact of the CAP on the economic sustainability of farms in the EU (Guth *et al.*, 2020) and, in general at farm and local level (Scozzafava & Casini, 2012). However, there are clear gaps between policy priorities and the statistical data infrastructure currently available to support policy assessments at farm level on sustainability issues. Therefore, European institutions need to monitor and evaluate EU programmes in the new CAP reform post 2020. This implies the need for a statistical database that is able to combine environmental, but also institutional and socio-economic dimensions with agricultural productivity. In this context, it becomes necessary to understand how policies can influence farmers' behaviour and decisions in a trade-off between different economic and environmental objectives but one of the most constraints is the lack of appropriate data. The literature highlights the difficulties associated with measuring sustainability at the farm level, mainly due to limitations associated with data availability. Some authors argue that accurate measurement is made difficult by the dynamism inherent in the concept of sustainability (Dillon *et al*., 2014). There are several statistics databases in the EU that are the main sources of agricultural data, and the FADN is a good example. Vrolijk *et al*. (2016) explain how FADN data allowed identifying some sustainability pillars aspects that they are able to help identifying problems and needs of farms. At the farm level, the existing FADN database refers to aspects expressing the technical and economic efficiency of farms (Coppola *et al*., 2020), with limited consideration of environmental, animal welfare, technology and innovation issues. These factors are particularly relevant for the evaluation of future policies assessment because farms sustainability takes into consideration the agroecological, economic and social criteria (Sulewski & Kłoczko-Gajewska, 2018). In a similar direction, Sulewski *et al*. (2018) investigate to measure and assess the interdependencies between dimensions of farms' sustainability. Due to the multidimensional nature of the concept of sustainable development, the measurement of sustainability is made on a different way. The literature on the subject offers a long list of researches to measure individual aspects of sustainability. Westbury *et al*. (2011) and Gerrard *et al*. (2012) provide the FADN contributions to sustainability questions merely in environmental terms. Highest contribution of FADN in terms of economics sustainability issues is found in Van Passel & Meul (2012) while some researches demonstrates the appropriacy of FADN data investigates the farms sustainability considering economic, environment and social pillar (Vitunskienė & Dabkienė, 2014; Barnes & Thomson, 2014; Van der Meulen *et al*., 2014; Ryan *et al*., 2016). In the field of agricultural sustainability assessment, Figuières *et al*. (2007) suggest to consider the interactions between farms and their business environment. In this regard, the existing literature agree on how the FADN has considerable potential to assess sustainability and competitiveness at the farm level in a European framework. Smędzik-Ambroży *et al*. (2019) determine the influence of the CAP on the level of socio-economic sustainability of farms in Poland using FADN data. Dabkienė (2016), argues on the farm sustainability assessment, in particular, the farm sustainability assessments based on EU FADN. Hennessy and Kinsella (2013) argue about the strengths of the FADN database and conclude that the FADN database provides a collection of directly comparable statistics on farms, supported by a robust data management, testing and validation infrastructure. Some authors highlight the valuable contribution that the FADN database can provide in the field of agricultural sustainability assessment and monitoring of robust on-farm performance (Mari, 2005; Longhitano *et al*., 2012). Performances monitoring is one of the strategies that support and affect the farms resilience (Darnhofer *et al*., 2010); in the absence of monitoring, sustainable economic, social and environmental management cannot be assumed. In the same direction, a recent study (2017) conducted by Poppe and Vrolijk, investigated existing methods for collecting farm sustainability data. The authors, through the publication FLINT project results, demonstrated the potential associated with the FADN database as an appropriate statistical tool to collect sustainability data. The authors stated that FADN database is adequately expresses the heterogeneity of the EU agricultural sector allowing different policies to be analysed. The results of FLINT project represent a significant challenge to expand the FADN database with the appropriate data to express the multi-disciplinary features of sustainability issues. A study by Buckley *et al.* (2017) argued in the same field and used national extensions of the EU farm accounting data network to obtain nationally representative nitrogen use efficiency indicators for dairy farms in Ireland and the Netherlands. Despite the considerable potential of the FADN database in providing answers to the new challenges emerging from the post-2020 CAP, a study conducted by Kelly *et al.* (2018) highlights the need to expand the scope of data collection through a broader assessment of sustainability at farm level and the need to include new information sets to address environmental issues. Indeed, the literature shows that there are many researches studies emphasising the appropriacy of FADN data for the sustainability and competitiveness analysis on farms: cases studies using data derived exclusively from FADN (Desjeux & Latruffe, 2010; Zhu *et al.*, 2011; Latruffe *et al.*, 2012; Lebacq *et al.*, 2013; Latruffe & Desjeux, 2016); studies using FADN data in association with national initiatives collecting additional data through the FADN (Pesti & Keszthelyi, 2009; Samson *et al.*, 2012; Dolman *et al.*, 2014; Ryan *et al.*, 2014; Dillon *et al.*, 2016); studies and researches using FADN data in combination with additional data from other sources than FADN, available nationally, at the EU or internationally (Letty *et al.*, 2012; Latruffe & Pie, 2014; Läpple *et al.*, 2015; Gillespie & Thorne, 2016).

2. Methodology

2.1. *Matherial and methods*

The applied methodology includes the multivariate analysis techniques, namely, Cluster and Factorial Analysis based on principal components. We use information and data from the FADN, the European database of the European Commission, to compare on two periods a classification of the strategic profiles identifying the farms of the Lazio Region, by following approach as suggested by Russo (2014), in this case simplified. According to our approach, development paths are attributed to individuals farms in the sample through the interpretation of factorial axes resulting from a factor analysis using the principal components method. The applied methodology allows to assess the sustainability and competitiveness of individual farms; their classification into groups of entities diversified by the degree of compliance with the principles of sustainable agriculture. The ability to measure and assess the sustainability of farms can be considered as the first step in the process of creating effective agricultural development support policies. In details, the data collected refer to the Lazio region (Italy) FADN sample, focus on two different years, 2011 and 2019. The analysed information and data are reported to the year 2019 because is the last one available, while we use the year 2011 because we believe that this year was the better year possible to analyse the CAP 2007-2013 implementation policies, namely, measures from the I and II Pillar of the CAP. On the other hand, starting from an in-depth analysis FADN data reported to the CAP 2007-2013, 2011 was the one year available without missing information and data on FADN thus an exhaustive dataset of appropriate data-information in representing the phenomenon as fully as possible. The decision to apply the empirical methodology to the analysis of Lazio's agricultural sector data is justified by the specific characteristics of the regional agricultural sector. In particular, the production and agricultural system in the Lazio region is characterised by structural and cyclical dynamics distinguished by a marked diversification of the activity oriented to multifunctional agriculture (Liberati & Di Fonzo, 2020). The existence of a multifunctional agriculture model has allowed to compare farms on two different periods, 2011 and 2019, in order to discuss the main implications on the farms of the last and current programming in terms of competitiveness and sustainability. Despite efforts to identify two periods as full as possible in the data availability and suitability, the findings of the analysis are not consistent in representing the phenomenon and this limits the possibilities to compare research results. FADN database has limitations due to the limited number of variables available and farms that are different for the 2011 and 2019, on the one hand, and, by the other, due to the high level of aggregation of data and information of the database. While the strategic profiles of the companies have been compared, considering the limitations of the analysis, the development trajectories attributed to the clusters, in the results section, exclusively refer to 2019.

Our approach allows us to interpret the findings as a representation of the status quo both before and after the start of implementation of the 2014-2020 RDP. In 2011, the sample contains 557 observations. The agricultural area considered in the analysis is equal to 17,731.48 hectares of TAA and 16,162.42 hectares of UAA. Average farm size is 31.9 hectares of TAA and 29 hectares of UAA. In 2019 the sample shows a greater number than in 2011 and it is represented by 584 farms, that absorb a total of 25,511.18 hectares of

TAA and 21,876.89 of UAA. Average farm size is 43.7 hectares of TAA and 37.5 ha of UAA[1].

In order to perform a factorial analysis with principal components methods necessary for the interpretation of the factorial axes, a database was developed to support the processing in order to systematize the collected data into SPAD dataset.

To simplify the interpretation and to compare the two periods covered, the farms are summarised in a small number of homogeneous groups defined using a cluster analysis (Jambu & Lebeaux, 1983; Russo & Sabbatini, 1998; 2002). Therefore, at the next stage, a mixed cluster analysis was performed based on the criteria of the optimal combinations that the software returned. Following this approach, the FADN variables collected from the survey have been sorted and processed to calculate the indexes (25) (reported in table 1) that are useful for the description of regional farms and used in the principal components analysis as active variables.

*Table 1 - Description of the indexes used in the Principal Components Analysis**

Indexes	*Indexes Description*
1. Arable crops area rate	Arable_crops area/UAA: it indicates the arable land area incidence compared to the utilized agricultural area.
2. Current cost rate	Current_Cost/GSP: it indicates the current cost incidence compared to the total gross salable production.
3. Europeansubsidies rate	Sub_EU/GSP: it indicates European subsdies incidence compared to the gross salable production.
4. Family labor rate	FWU/AWU: it indicates the unpaid labor incidence compared tothe farm's total labor force.
5. Forest area rate	Forest_area/TAA: it indicates the forest area incidence compared to the total agricultural area.
6. Gross agricultural labour productivity	GSP/AWU: it indicates the unitary productivity compared to farm revenues.
7. Gross agricultural land productivity	GSP/UAA: it indicates the unitary productivity of the utilized agricultural area.
8. Irrigation systems rate	Irrigation_systems/UAA: it indicates the irrigation systems incidence compared to the utilized agricultural area.
9. Land capitalization	Land and buildings/AWU: it explains the intensity degree of landed capital use compared to the labor total units.

1. The difference in data than census depends on the universe of reference of the two surveys, quite different. In fact, the FADN field of observation does not consider smaller farms as it applies minimum size thresholds.

Table 1 - Continued

Indexes	*Indexes Description*
10. Land intensity	Land and buildings/UAA: it indicates the soil intensity degree of the landed productive factor and of the capital invested on it.
11. Land intensification degree	ALU/AWU: it indicates the availability of agricultural area for work unit.
12. Land mechanization degree	kW_Machine/UAA: it indicates farm mechanization degree compared to the utilized agricultural area.
13. Meadows and pastures area	Meadows_pastures_area/UAA: it explains the land used incidence for the cultivation of grass or other herbaceous forage plants compared to the utilized agricultural area.
14. Net land productivity	VA/UAA: it expresses the net productivity of the utilized agricultural area.
15. Net land profitability	Net_Income/UAA: it explains the net profitability of family work.
16. Nitrogen rate	Nitrogen_per_hectare/UAA: it indicates the amount of nitrogen used compared to the utilised agricultural area.
17. Phosphorus rate	Phosphorus_per_hectare/UAA: it indicates the amount of phosphorus used compared to the utilised agricultural area.
18. GSPdirect sales rate	GSP_direct sales/GSP: it indicates the gross salable production incidence relating to direct sales compared to total gross salable production.
19. GSP processing rate	GSP_processing/GSP: it indicates the gross salable production incidence relating to processing compared to the total gross salable production.
20. GSPquality rate	GSP_quality/GSP: it indicates the gross salable production incidence relating to quality compared to the total gross salable production.
21. Potassium rate	Potassium_per_hectare/UAA: it indicates the amount of potassium used compared to the utilised agricultural area.
22. Tree area rate	Tree_area/UAA: it expresses the incidence relating to area destined for tree crops compared to the utilized agricultural area.
23. UAArate	UAA/TAA: it indicates the utilized agricultural area incidence compared to the total agricultural area.
24. ALUrate	ALU/UAA: it indicates the livestock unit incidence compared to the utilized agricultural area.
25. Water usage	Total_water_volume/UAA: it explains the water volume used compared to the utilized agricultural area.

* PLV: Gross Salable Production; UBA: Adult Livestock Unit; TAA: Total Agricultural Area; UAA: Utilized Agricultural Area; FWU: Family Working Units; AWU: Annual Working Units; VA: Value Added.

The axes resulting from factorial analysis are defined through positive or negative correlation with the variables used. The interpretation of the axis-variable associations, according to the system theory of the farm, allows the factor to be used as a conceptual category that explicates the agricultural sector. In order to generate a coherent interpretative framework, the factorial axes sort the factors according to their ability to reflect the variance in the data or their ability to interpret it. As a consequence, the conceptual scheme does not fully represent the phenomenon, but the choice of the combination, even if not exhaustive, is the best possible illustration. The first factorial axes resulting from the principal components analysis can be interpreted as follows:

1. Factorial_axis (1): Competitiveness. Based on the semantic contrast between public support on the one hand and profitability/productivity of the land, on the other. The axis represents the dichotomy between income and profit as an entrepreneur objective to be optimized. The competitiveness is defined as the ability of the farm to provide adequate input returns through market access.
2. Factorial_axis (2): Functional diversification. The axis shows the paradox between opposite semantics, represented on the one hand, by the productivity of the land and, on the other, by the presence of certified quality production (local and organic products) and of food processing and direct sales. In terms of production, the contradictions are associated with the production of arable crop and the presence of permanent crops. The result is a dichotomy between a productivity approach and multifunctionality, where the last is interpreted as the multiplicity of functions performed by farms, as against specialisation in the agricultural function.
3. Factorial_Axis (3): Environmental pressure. The axis includes the dichotomy between the use of agricultural land for crops and the use for forests and pastures. The emerging duality opposes the preservation and exploitation of the land resource and shows the different degree of stress that agricultural activity places on the natural environment and land.

3. Results

The applied multivariate analysis technique (clustering) found five different clusters of farms in Lazio region, in both periods considered. The representation of the strategic profiles that grouped the farms, variables and structural indexes are described below and presented in Tables 2 and 3 for 2011 and in Tables 4 and 5 for 2019.

Table 2 - Main collected variables distribution infarms profiles (average value, 2011)

	TAA	UAA	ALU	GSP	Net income	UAA irrigated	AWU	VA	Sub.EU
Sample mean	31,88	29,07	32,54	108.992	41.507,63	8,29	2,04	70.677,14	9.416,47
Homologated farms family	11,50	10,20	2,57	57.031,67	29.542,28	3,26	1,45	44.654,37	2.116,69
Resilience	23,29	7,00	8,14	28.558,43	3.937,86	1	1,29	20.233,43	108
Livestock farms	67,38	63,48	74,56	62.298,58	30.786,92	0,69	1,40	44.125,50	8.040,65
Large capitalized farms	35,37	32,36	38,54	132.716,22	47.527,73	11,30	2,32	83.366,47	12.512,92
Services farms	1,37	0,95	0,53	111.584,11	38.255,21	2,37	2,32	68.076,47	531,21

Table 3 - Main indexes distribution in farms profiles (average value, 2011)

	UAA rate	ALU rate	% Family work	Sub EU rate	Land mechaniz.	GSP proces. rate	GSP qual. rate	GSP dir. sal. rate	Irrigation system rate	Land net profitability
Sample mean	0,98	2,08	0,81	0,02	21,57	0,08	0,03	0,05	0,48	4.449,40
Homologated farms family	1	0,19	0,90	0	17,19	0,26	0,10	0,10	0,37	2.872,22
Resilience	0	1,71	0,71	0	46,86	0,14	0	0	0,43	2.564,43
Livestock farms	1	5,40	0,92	0	6,92	008	0	0,04	0,04	882,19
Large capitalized farms	1	2,08	0,78	0,02	16,78	0,03	0,02	0,04	0,50	3.747,55
Services farms	0,95	5,11	0,63	0	168,68	0	0	0,05	2	37.295,58

Table 4 - Main collected variables distribution in farms profiles (average value, 2019)

	TAA	UAA	ALU	GSP	Net income	UAA Irrigated	AWU	VA	Sub UE
Sample mean	43,74	37,52	43,57	133.937,33	57.640,16	5,78	1,97	90.337,52	11.915,13
Homologated farms family	17,66	15,58	2,39	93.343,5	40.303,54	4,11	1,92	68.303,73	4.097,60
Resilience	57,28	17,71	35,14	107.442	34.486,28	0,71	2,21	67.704,28	3.467,85
Livestock farms	123,28	105,09	61,19	176.577,82	67.696,32	7,63	1,84	11.116,10	29.132,54
Large capitalized farms	32,31	29,14	55,32	131.758,85	58.185,60	5,98	1,92	86.430,95	11.088,61
Services farms	5,90	5,14	60,09	250.050,33	130.797,71	8,47	3,28	209.959,52	926,04

Table 5 - Main indexes distribution in farms profiles (average value, 2019)

	UAA rate	ALU rate	% Family work	Sub EU rate	Land mechaniz	GSP proces rate	GSP qual. rate	GSP dir.sal. rate	Irrigation system rate	Land net profitability
Sample mean	0,97	6,28	0,81	0,02	12,49	0,07	0,06	0,12	0,21	3.163,38
Homologated farms family	1	0,67	0,82	0	13,69	0,24	0,15	0,18	0,28	2.035,19
Resilience	0	2,71	0,64	0	8,07	0,14	0,07	0,50	0,07	1.985,35
Livestock farms	1	0,77	0,73	0,13	3,20	0,01	0,01	0,01	0,03	726,88
Large capitalized farms	1	2,51	0,87	0	11,75	0,03	0,05	0,10	0,21	2.433,19
Services farms	0,90	126,38	0,52	0,05	61,67	0,05	0,10	0,29	0,61	33.358

Cluster (1)_Homologated family farms. This cluster describes the medium to large size farms, where most of the work is provided by the farmer and his family (between 80 and 90% on average). The farms intensively exploit the agricultural area (between 85 and 90% of the UAA). There isn't a significant diversification of agricultural activities and no significant use of quality labels. The relevant presence of vegetable gardens suggests the importance of the residential function and agricultural consumption. The property of land and buildings, machinery and livestock is lower than the regional average. This results in profitability indexes below the regional average and a high incidence of European subsidies on the farm balance sheet. This cluster is placed on development paths linked to economies of scale and cultivation.

Cluster (2)_Large capitalized farms. Farms grouped in this cluster are distinguished by the large availability of land capital, mechanical and livestock, that allows to achieve a high value of GSP even with a relatively limited use of labour. As a result, the labour productivity indexes are particularly high (over 130,000 Euros). The intense exploitation of the soil is also confirmed by the high incidence of UAA on the TAA. The large size and the type of production in arable crops allow these farms to benefit European subsidies, that have an important impact on the farm's balance sheet. The development trajectory of the cluster appears linked to the exploitation of economies of scale resulting from access to large amounts of capital. Farm's investments make it possible to offer the labour factor and the farmer high remuneration. The relevant estimated number of the cluster makes it particularly important for policy assessment purposes. The development paths are linked to economies of scale and cultivation.

Cluster (3)_Resilience. This cluster includes farms smaller than the average, characterized by low income and labour related almost entirely to the farmer and his family. The economic size is clearly below average, with a farming practised that sees prevailing arable crops and presumably self-consumption animal husbandry. Given the small areas, EU payments do not reach an average of 3,500 euros, even if they significantly affect the balance sheet. Farm survival appears to be linked to the residential and use function, as well as the possibility of integrating with additional income (including retirement). The distinctive feature of the cluster is identified in a strategic choices lack and an indefinite development path.

Cluster (4)_Livestock farms. The discriminating element of this cluster is the presence of grazing areas, that absorb a modest percentage of the TAA. The farms have a large surface area (over 60 ha) and a substantial livestock capital (between 60 and 75 ALU). However, they are characterized as medium-sized farms, with a ALU/Ha ratio between 5 and 7.

Cluster (5)_Services farms. They are distinguished by the importance of the component services in the farm balance sheet. Faced with a modest GSP, these farms develop high value added and substantial income by non-agricultural activities. The development paths are related to land productivity and services.

Figures 1 and 2, respectively, for 2011 and for 2019, report the percentage composition of the grouping for the reference sample.

Figure 1 - Percentage frequencies distribution in the strategics farms profiles (2011)

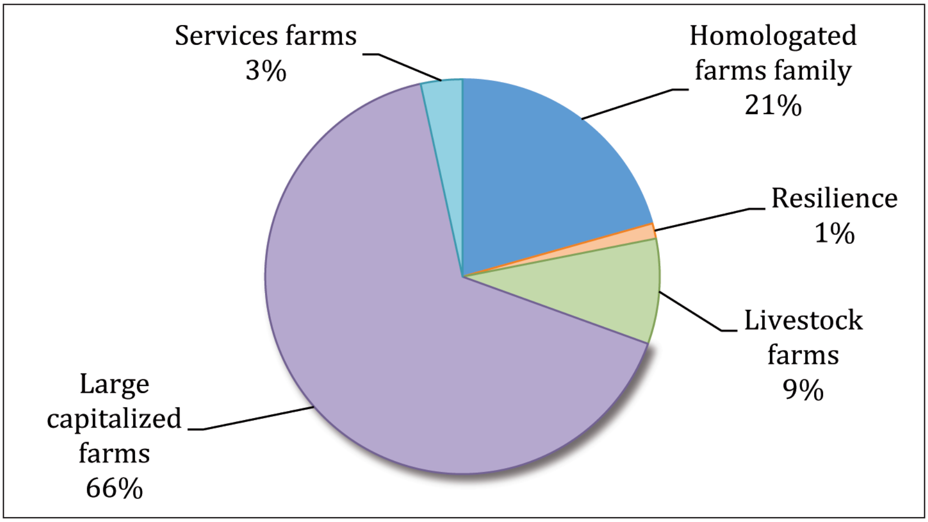
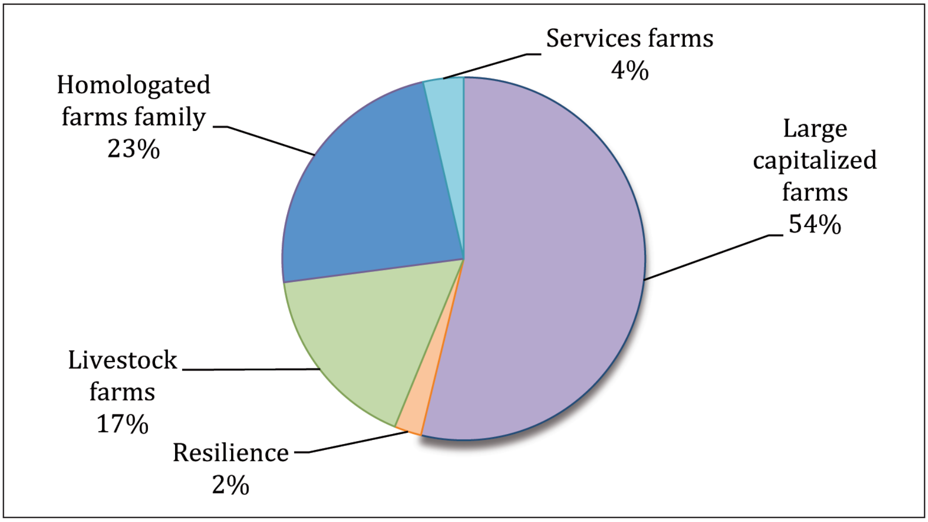


Figure 2 - Percentage frequencies distribution in the strategics farms profiles (2019)



The results, in particular, the five different cluster identified in Lazio region also conclude that Lazio agriculture and their respective farms have moderate sustainability where the subsidies from CAP have a positive impact on. Moreover, agricultural activity in the Lazio region presents a moderate contribution in environmental terms. The main conclusion highlights the need to better adjust agricultural policies among the European Member States in order to better promote the sustainability of agriculture in Europe.

4. Conclusions

This paper illustrates a multivariate analysis (clustering) on the data collected from a representative sample of farms from the FADN survey in the Lazio region, in order to describe the possible development paths that drive the choices of the farms towards a production model that is increasingly competitive as well as sustainable. The farms covered by the analysis were identified through a model of classification into categories based on explanatory indexes of structural characteristics and sustainable behaviour. The results obtained in the periods considered (2011-2019) select five profiles of farms, each one united by elements of competitiveness and sustainability in a homogeneous set of data composed of structural, economic and environmental variables.

The finding of this study aims to merely present a description of a agricultural system of Lazio region, that although not characterised by profound mutations, the changes in the groups' structural composition require some reflection. In fact, between 2011 and 2019, the reduction of capital farms (–12%) reflects in 2019 a path of development of farms aimed at increasing the use of sustainable production methods, such as livestock farming. The simultaneous presence of diversification of activities (with particular incidence of forests and pastures) and the related public subsidies reflects forms of environmental monitoring.

The moderate increase in the number of family farms and resilient shows the dependence of the farm competitiveness on the presence of European payments. This result is supposedly due to delays in the use of RDP 2014-2020 funds that are not still used by producers or farms that have partially benefited from them. Nowadays, the EU and national objectives are to use new transition rules to accelerate the implementation of the expenditure programmes. The increasing trend in service farms, however slight, represents an amplification of farm functions, which reflects a multifunctional agricultural development path. Our paper, despite methodological limitations discussed, aims to contribute to the literature that argues the contributions of FADN in the assessment of CAP policy and its supporting measures. In this direction, the proposal put forward by the European Commission is oriented towards greater simplification efficiency and sustainability. The thematic objectives of the 2014-2020 period have been summarised in 5 policy objectives of cohesion policy 2021-2027, to ensure a greater flexibility also in the transfer of resources within a priority. These include "A Greener Europe" to promoting energy efficiency measures; promoting renewable energies; promote adaptation to climate change, risk prevention and disaster resilience; promote sustainable water management; promote the transition to a circular economy. In the view of these considerations, the Commission's CAP reform proposal is strong integrated with the Green Deal programme. The need to measure and monitor sustainability led the Commission will propose legislation to convert its Farm Accountancy Data Network (FADN) into the Farm Sustainability Data Network with a view to also collect data on the Farm to Fork targets and other sustainability indicators. In this framework, FADN represents a valuable statistic tool in the Common Monitoring and Evaluation Framework (CMEF) for assessing the functioning of the Common Agricultural Policy (CAP) and improving its efficiency to measure the performance of the whole CAP (both Pillar I – direct payments to farmers and market measures – and Pillar II – rural development measures).

On the issue discussed, future research could branch out in different directions. Faced with one of the main limitations of the current study, it would be appropriate to analyse the farms profiles, defining them in more detail for better external consistency of the results. This could be achieved, for example, by selecting more explanatory variables of sustainability, which by definition (multidimensional character) is a complex concept. Finally, the results of our study could be applied in other regions, geographic areas or on a national level, or have a more integrated view on the issue.

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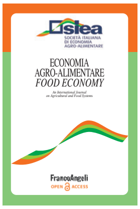
Economia agro-alimentare /
Food Economy

An International Journal on Agricultural and Food Systems

Vol. 23, Iss. 3, Art. 13, pp. 1-24 - ISSN 1126-1668 - ISSNe 1972-4802
DOI: 10.3280/ecag3-oa12773



Economic characterization of irrigated and livestock farms in The Po River Basin District

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Abstract

This article highlights the potential for collecting and processing territorial data in order to facilitate planning and programming that respond to real local problems and include the political and regulatory framework in force. A case study is explored that involves the joint use of two databases with institutional functions: the Farm Accountancy Data Network (FADN) and the National Information System for Water Management in Agriculture (SIGRIAN). Both databases are managed by the Council for Agricultural Research and Economics (CREA). Those data were used to calculate economic-structural indicators for irrigated and livestock farms located in the Po River Basin District and to run the socio-economic analysis required to update the Water Management Plan. The updating of plans is governed by the Water Framework Directive (Directive 2000/60/EC), which establishes the community framework for water and requires all Member States to review and update their Plan every six years. The first update deadline was December 2015 and the second one will be December 2021. The integrated use of two databases made it possible to identify farms according to two types of irrigation:

Article info

Type:
Article
Submitted:
17/05/2021
Accepted:
27/09/2021
Available online:
12/01/2022

JEL codes:
Q15, Q18, Q50

Keywords:
Irrigation
FADN
SIGRIAN
Water Management Plan
Socio-Economic Analysis

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collective or self-supplied. With collective irrigation (Irrigation Water Service), the farm is a user of a Local Agency for Water Management (LAWM) that collects and distributes irrigation water. With self-supplied irrigation, the individual farmers collect and distribute water themself. The analysis carried out demonstrates the need and opportunity to develop coordinated data collection and management systems, thereby strengthening and refining the monitoring and programming of water use in line with the real needs of the territory.

Managing Editor:
Lucia Briamonte,
Luca Cesaro,
Alfonso Scardera

Introduction

Sustainable water management and the adaptation of the agricultural sector to climate change have become important issues within the international, European and national political contexts (FAO, 2017). Indeed, access to water and efficient water management are included in the 2030 Agenda for Sustainable Development Goals (UN, 2015). The increasing frequency and intensity of extreme climate phenomena (IPCC, 2014) necessitate more efficient water resource management for household, industrial, energy and agricultural uses (Benedetti *et al.*, 2019). Water resource management has a strategic function in terms of ensuring international food security amidst growing global demand for food (FAO, 2011; 2012).

Irrigation not only allows farmers to be flexible in choosing the production systems (INEA, 2009), but it also plays an important role already at the level of the economy of each individual farm, simply because it represents the most important element of intensification in agricultural production (Columba, Altamore, 2006). The immediate consequence of crop intensification, made possible by the water factor, is that farmers invest many of their other resources, such as working units and capital employed, in the irrigation sector instead of in the non-irrigation- related ones. Irrigated crops, especially crops with high market value, contribute significantly to the gross saleable production (GSP) of farms and the efficient use of water resources allows a quantitative and qualitative improvement of production, which is essential in securing a role in the national and especially international scenario. Non-restrictive access to water also allows for irrigation of crops that not necessarily need water, leading to an increase in the value of production and therefore of the farm's income.

In Italy, the agricultural sector produces added value, guarantees employment, and generates an important flow of exports that promote the quality of agri-food production (CREA, 2021). Irrigated agriculture also plays a decisive role in protecting the natural territory and in generating important environmental benefits for ecosystem services (MEA, 2005; Van der Meulen *et al*., 2018; Dominati *et al*., 2010; Adhikari and Hartemink, 2016). Many of these benefits are positive externalities of production whose economic value is not recognised by the market (Natali and Branca, 2020).

Positive environmental externalities generated by agricultural irrigation include: (i) water regulation in terms of nutrient cycle and conservation of the territorial hydrogeological balance, water purification and assimilation of waste (e.g. aquifer recharge and water vivification), counteracting the rising saline wedge and soil salinization, and reduction of hydraulic and flood risk; (ii) improved natural habitats and increased plant and animal biodiversity, reduced risk of forest fire and parasite attacks on grassland-pastures, and protection of wetland biodiversity; (iii) improvement and enhancement of the rural landscape and its socio-cultural and recreational aspects (e.g. the historical canal system, hydraulic knots and artefacts, fountains, or hedges and rows associated with sliding channels which are important in combating the trivialization and urbanization of the landscape); (iv) crop diversification towards more environmentally sustainable crops, such as the maintenance of pasture meadows and the increase in fodder crops that allow longer-lasting land cover with benefits for organic matter and its carbon tanks (Bellver-Domingo *et al*., 2016; FAO, 2019; Jandl, 2010; Martin-Ortega *et al*., 2015; Peter *et al*., 2008).

The Common Agricultural Policy (CAP) environmental objectives – both current objectives and those post-2022 – are strongly interconnected with European regulations aimed at the protection of natural resources, and primarily the Water Framework Directive 2000/60/EC (WFD). With the adoption of the WFD, water is no longer assessed as a mere productive resource; rather, due to its many functions, it is considered an essential element in ensuring stability in ecosystems and sustainability in general. The WFD emphasises economic value and makes use of tools and incentives such as volumetric pricing to achieve environmental objectives. Moreover, it introduces the concept of "full cost" (Gallerani, Viaggi, 2006), which not only includes financial costs, but also the opportunity cost, that is quantified on the basis of alternative uses of water and environmental costs. By including the opportunity cost, the use of water mainly in more profitable activities is encouraged, thus reducing waste as much as possible. Finally, the aim of environmental costs is to apply "the polluter pays" principle, thereby discouraging the generation of this type of costs (Dono, Severini, 2006). For this reason, water management programming provided by the WFD is in line with the future CAP programming through the preparation of National Strategic Plans by the Member States.

This difficult challenge entails obstacles typical of water resource management that derive from the variety of interconnected territorial competences and programming approaches, all of which address productive enhancement or environmental protection. From this point of view, considering the competences composition of Regions and Ministries, it is not risky to hope that the implementation of the WFD and the CAP can help each other, experimenting virtuous synergy or exploiting experiences and past mistakes.

The WFD and the CAP both promote efficient and sustainable water resource management, reduce agricultural pressure on the quantitative and qualitative state of surface and groundwater, and general maintenance of water bodies. In addition to the CAP, the *European Union's Green Deal the "Farm to Fork"* and biodiversity strategies may have significant implications for water resource management for agriculture. Optimum use of water resources must entail protecting quality and preventing the leaking of pesticides and fertilizers that can generate negative externalities in the environment.

In line with the WFD, each Member State divided its territory into River Basin Districts[1], the territorial reference unit for sustainable water resource management. In Italy, there are seven Riven Basin District Authorities: the Po River, the Eastern Alps, the Northern Apennines, the Central Apennines, the Southern Apennines, Sicily, and Sardinia.

The River Basin District Authorities (RBDAs) are responsible for implementing the operational measures in the Water Management Plans (WMP) in order to achieve the environmental objectives of the WFD. The analyses of the characteristics of River Basin Districts required by Article 5 of the WFD, the impact of human activities on surface and groundwater, and the economic analysis of all water uses (including agricultural) adhere to the WMP. The WFD expects the drafters of the WMP to be supported by an economic analysis of the social and economic sustainability of environmental measures.

Since the first planning cycle (2011-2015), the economic analyses by RBDAs have not been performed in a uniform way, due to a lack of information sources and the difficulty of comparing and processing conflicting data. For this reason, the European Commission formalised a pre-litigation procedure (EU Pilot 7304) for the application of RBDAs economic analyses in the drafting of the WMP. In response, the current Ministry of Ecological Transition (MiTE) launched an action plan to develop an operational and methodological Manual for Economic Analysis (MEA), to be drafted in consultation with the RBDAs, the Ministry of Agricultural, Food and Forestry Policies (MiPAAF), the Council for Agricultural Research

1. Land and sea area, consisting of one or more neighbouring hydrographic basins and their respective groundwater and coastal waters.

and Economics (CREA), the Regulatory Authority for Energy Networks and Environment (ARERA) and the National Statistical Institute (ISTAT) (MATTM, 2018)[2].

The economic analysis in support of the WMP is, therefore, drawn up in accordance with the MEA, which provides valid and uniform indications throughout the national territory. The MEA established indicators for each type of water resource use and service. Many of these indicators require economic data from the Farm Accountancy Data Network (FADN), particularly data from the socio-economic analysis of the collective water service, self-supply irrigation, and livestock use.

The aim of the present article is to highlight the potential for collecting and processing territorial data in order to facilitate planning and programming that respond to real local problems and include the political and regulatory framework in force. A case study is explored that involves the joint use of two databases with institutional functions: the Farm Accountancy Data Network (FADN) and the National Information System for Water Management in Agriculture (SIGRIAN). Both databases are managed by the Council for Agricultural Research and Economics (CREA).

The joint use of the FADN and SIGRIAN databases can provide the information necessary for socio-economic analysis. An opportunity also exists to expand the database on irrigation water use. This would improve the performance of agricultural and environmental policies.

The introduction of new variables concerning irrigation systems in the FADN database and monitoring of information being constantly added to the SIGRIAN database on the one hand, and the joint use of these data on the other, would guarantee a complete and shared knowledge of the management of water resources in agriculture. This is an important concept both at the national and international level and includes social and economic sustainability as well as environmental and agronomic aspects. This could lead to the creation of a system for monitoring the sustainability of farms and evaluating the performance of sustainable and certified food systems.

The benefits of such an approach are borne out in the results of a socio-economic analysis of irrigation and livestock in the Po River Basin District (which includes the Regions of Piedmont, Valle d'Aosta, Lombardy, and Emilia-Romagna, and partly the territory of Liguria, Veneto, Tuscany, Marche, and the Autonomous Province of Trento).

The data and methodology, results, and final considerations of that analysis are presented below.

2. This Manual represents, among other things, the application and complementary tool to the MITE Decree of 24 February 2015 no. 39 "Regulation containing the criteria for defining environmental and resource costs for the various sectors of water use".

1. Methodology and databases

The economic and structural indicators required by the MEA for different agricultural uses concern employees, total turnover, turnover per employee, and value added for the two years referenced: 2016 and 2018[3].

Irrigated agricultural use includes the following aspects:

- the Irrigation Water Service (i.e. the water service provided collectively by Local Agencies for Water Management - LAWMs);
- the self-supply irrigation (defined in Article 6 of RD 1775/1933);
- water for livestock and aquaculture.

Collective irrigation is managed by LAWMs, which can be of a public (Reclamation and Irrigation Consortia) or private legal nature. According to the Ministry of Agriculture Guidelines[4] (M.D. 31 July 2015) LAWMs are required to join the National Information System for the Management of Water Resources in Agriculture (SIGRIAN). Within the SIGRIAN, the territory of each LAWM is divided into irrigation areas, i.e., physical, and administrative territorial units served, in whole or in part, by a system of irrigation networks. In general, the area is defined by as irrigated with respect to the development of an irrigation scheme[5], in each area of its territory, that is a territorial unit that identifies areas equipped for irrigation. The irrigation areas are divided into LAWMs, i.e. areas where the water distribution network is developed powered by its own divider[6].

The self-supply irrigation by farmers, who are not associated and served by LAWMs and therefore do not fall within the Irrigation Water Service (IWS), constitutes withdrawal in self-supply. The availability of SIGRIAN information on areas falling within LAWMs and served by irrigation services makes it possible to calculate areas potentially affected by self-supply withdrawals by difference. This estimate assumes that wells or other self-supply methods are not in use in the LAWMs territories. Unfortunately, the current information system does not make it possible to verify whether and to what extent this assumption is true, in the lack of a timely and reasonably complete collection of self-supply sampling points in the agricultural context.

3. The 2017 agricultural year is not considered because it has been characterized by extreme weather conditions.

4. Ministerial Decree 31/07/2015 of Ministry of Agriculture "Guidelines for the regulation by the regions of the methods for quantification of water volumes for irrigation".

5. All the hydraulic infrastructure necessary for the distribution of water for irrigation purposes; it consists of a source of supply from which the supply network to which the distribution network is connected branches out and which distributes water within the individual irrigation districts. SIGRIAN currently collects information about the main network and only partially the distribution network.

6. Hydraulic structure for the delivery of water to the consortium distribution network.

The data of the FADN used in the description of the farms are both structural and economic: there are elementary data on the business structure such as Technical Economic Orientation (TEO), Economic Dimension Unit (EDU), class of Utilized Agricultural Area (UAA), values of UAA, Total Agricultural Area (TAA) and irrigated, Adult Livestock Units (LU), Working Units (WU); balance sheet data such as total revenue, added value, and net income; data on certifications for animal species such as the type and subject of certification; crop data which include the plant species, the cultivation method, the relative total production; information on the cost of labour and on the irrigation systems present.

The FADN survey is a sample survey in which a sample of farms that are statistically representative of the national reality is extracted each year. The information listed above refers exclusively to the farms in the sample, but can be extended to the regional level, using multiplicative factors relative to the variables. However, no carry-over to the regional level was carried out since, being the FADN data classified by Region, for the Regions that are only partially included in the Po River Basin District the data would present a certain degree of imprecision. Therefore, it was decided to report the average data of the farms since, being a sample survey, it would not be correct to analyse the overall data. Furthermore, the FADN does not consider farms with Standard Production lower than 8,000 euros which, therefore, are not included in the sample survey. These farms are of very small size, both economic and physical, but the high number of these small and very small farms in the Italian national territory could lead to a non-negligible distortion in the representation of the analysed reality.

It is important to underline that the aim of these two databases is not the same. The FADN's priority task is to collect information for the definition and evaluation of the CAP through the simulation of different scenarios on farm sustainability (economic, environmental, social and innovations); SIGRIAN was created in 1994 in order to collect information on the irrigation water service. In 2015, in order to respond to the ex-ante Conditionalities for water resources, according to the Ministry of Agriculture Guidelines (M.D. 31 July 2015)[7], SIGRIAN became the national tool for quantifying and monitoring water volumes for irrigation both for the Irrigation Water Service and for self-supply irrigation. The two databases therefore contain complementary information on irrigation. Over the years, the FADN database has been updated with additional information on irrigation although to date it does not contain a breakdown of farms by type of irrigation used.

The FADN database used for the socio-economic analysis reports useful parameters for calculating the economic-structural indicators required by

7. The guidelines are finalized to promote the use of water metering and the application of water prices based on the volumes used in agriculture.

the MEA; it reports the municipality to which it belongs, the farm code and the geographical coordinates for the distinction of farms using the Irrigation Water Service and the self-supply irrigation, carried out through cartographic analysis.

The FADN dataset was reported in a Geographic Information System (GIS) software, using files in Comma Separated Value (CSV)[8] format and the farms coordinates in the sample for the two years, 2016 and 2018. This, in order to be able to cross with the *shapefiles* of the Po River Basin District and the LAWMs in the SIGRIAN Web-GIS platform, on a regional basis. It was thus possible to discriminate between the farms in the FADN sample falling within the limits of the SIGRIAN LAWMs (analysed in the Irrigation Water Service) and the farms falling outside the limits of SIGRIAN LAWMs (analysed in the self-supply irrigation).

Livestock farms, on the other hand, were isolated, on a regional basis, considering Adult Livestock Unit (LU) values greater than zero.

2. Results and discussion

2.1. *Economic-structural indicators of Farms using Irrigation Water Service*

In the study of Irrigation Water Service by FADN data, only the farms included in the SIGRIAN LAWMs have been considered. Tuscany and Liguria do not appear, in fact, in their territory included into the Po River Basin District, there is only self-supply irrigation.

To mitigate the impact of annual variability in the assessment, two years were considered: 2016 and 2018. Since the variability between those two years is relatively small, the data for 2018 will be discussed in general, keeping 2016 as a frame of reference.

In 2018, the sample consists of 54,873 farms, distributed as follows: 20,063 in Emilia Romagna, 14,691 in Lombardy, 11,794 in Piedmont, 334 in the A.P. of Trento, 867 in Valle d'Aosta and 7,124 farms in Veneto.

Starting from the analysis of farm Agricultural Area (Table 1), in the Regions and Autonomous Province (A.P.) it is equal, on average, to 35.6 hectares in 2018, compared to 31.3 hectares in 2016. The Utilized Agricultural Area (UAA) is, on average, equal to 27.5 hectares in 2018. The minimum value is recorded in the Autonomous Province of Trento, with 4.6 hectares in 2018, while the maximum values are found in Valle d'Aosta with 33.2 hectares in 2018. These values can be justified by the circumstance that

8. Comma Separated Value: Text files made up to contain information in a table-like manner. It is a file format that allows the transfer of data from one program to another.

farms with less than 8,000 euros of Standard Production are not included in the sample study, as mentioned above. This barrier means that the fruit farms of the A.P. of Trento with limited areas are, in any case, included in the analysis because of the high value of their production per hectare; quite the opposite happens for farms in Valle d'Aosta, where only the larger ones are included because they exceed the minimum threshold.

Table 1 - Average Agricultural Area (TAA), Average Utilized Agricultural Area (UAA) and Average Irrigated Utilized Agricultural Area for Farms into LAWN, years 2016 and 2018

Regions	Average farm TAA (ha)	Average Farm UAA (ha)	Average Farm Irrigated UAA (ha)	Average Farm TAA (ha)	Average Farm UAA (ha)	Average Farma Irrigated UAA (ha)
		2016			2018	
Emilia Romagna	32,87	30,32	10,58	30,18	27,96	7,80
Lombardy	31,86	30,19	26,73	53,69	28,66	24,92
Piedmont	32,28	30,76	25,56	30,69	29,57	21,70
A.P. Trento	–	–	–	4,83	4,59	2,60
Valle d'Aosta	90,71	46,19	8,37	37,49	33,23	6,70
Veneto	22,34	20,39	7,81	22,52	20,72	10,02
The Po River Basin Authority	**31,31**	**28,73**	**15,69**	**35,55**	**27,50**	**15,61**

Source: CREA PB processing about FADN and SIGRIAN data.

As of Working Units (WU), the situation is quite homogeneous among the Regions and the A.P. considered, with values around 1.5 WU per farm (Table 2).

For the irrigated UAA (Table 3), at farm level, there is significant variability among the Regions and the A.P. considered. The average value of the irrigated area on the UAA is equal, in 2018, to 56%; more than half of the average UAA is irrigated, with the highest value recorded in Lombardy (86%) and the lowest value in Valle d'Aosta (20%). In two other important Regions for the Po River Basin District, Piedmont and Emilia-Romagna, the ratio of irrigated UAA to UAA is 73% and 27% respectively.

Another important indicator is the ratio between UAA and WU, which indicates the number of hectares for each WU present on the farm. The average value of the UAA/WU ratio, in 2018, is 18.3 he/WU, with the maximum value in Piedmont (21 he/WU) and the minimum value in the A.P. of Trento (4.2 he/WU). In Piedmont, Lombardy and Emilia Romagna, the ratio is 21, 19.5 and 17.1 he/WU, respectively.

Table 2 - Average Work Unit (WU), Average Total Revenue (TR) and Average Added Value (AV) for Farms into LAWN, years 2016 and 2018

Regions	Average Farm WU	Average Farm TR (€)	Average Farm AV (€)	Average Farm WU	Average Farm TR (€)	Average Farm AV (€)
		2016			2018	
Emilia Romagna	1,59	129.481,47	73.426,25	1,63	119.956,24	67.315,09
Lombardy	1,62	183.316,20	105.578,78	1,47	173.560,92	89.262,51
Piedmont	1,86	161.407,78	89.897,19	1,41	102.256,84	52.546,48
A.P. Trento	–	–	–	1,09	81.117,34	63.992,78
Valle d'Aosta	2,04	54.516,47	32.280,34	1,67	59.339,66	34.250,90
Veneto	1,12	85.121,67	46.285,68	1,35	100.222,05	57.258,27
The Po River Basin Authority	**1,55**	**136.965,75**	**77.470,26**	**1,50**	**126.747,14**	**68.168,43**

Source: CREA PB processing about FADN and SIGRIAN data.

Table 3 - Structural indicators for Farms into LAWN, years 2016 and 2018

Regions	UAA/TAA	Irrigated UAA/UAA	UAA/WU	UAA/TAA	Irrigated UAA/UAA	UAA/WU
		2016			2018	
Emilia Romagna	0,92	0,34	19,12	0,92	0,27	17,09
Lombardy	0,94	0,88	18,59	0,53	0,86	19,49
Piedmont	0,95	0,83	16,50	0,96	0,73	20,95
A.P. Trento	–	–	–	0,95	0,56	4,20
Valle d'Aosta	0,50	0,18	22,65	0,88	0,20	19,85
Veneto	0,91	0,38	18,25	0,91	0,48	15,31
The Po River Basin Authority	**0,91**	**0,54**	**18,51**	**0,77**	**0,56**	**18,28**

Source: CREA PB processing about FADN and SIGRIAN data.

A marked variability in economic data, such as total revenue (TR) and added value (AV) can be observed. Also, with respect to these variables, to mitigate seasonal variability, data are reported for two years: 2016 and 2018. As shown in Table 4, variations are found between the two years considered but these differences can be considered in a small range of variation, demonstrating that the sample is robust. Consequently, for consistency with the other information reported, it seems justifiable to comment only on the data for 2018.

For the TR/WU ratio in 2018, an average value of 84,278 euros is recorded. The highest value is recorded in Lombardy (118,017 euros),

Table 4 - Economic indicators for Farms into LAWN, years 2016 and 2018

Regions	**TR/WU**	**TR/UAA**	**AV/WU**	**AV/TR**	**TR/WU**	**TR/UAA**	**AV/WU**	**AV/TR**
	2016				**2018**			
Emilia Romagna	81.665,07	4.270,08	46.310,56	56,71%	73.329,08	4.289,04	41.149,62	56,12%
Lombardy	112.915,06	6.072,71	65.032,08	57,59%	118.017,16	6.054,27	60.696,31	51,43%
Piedmont	86.605,74	5.247,89	48.235,67	55,70%	72.451,17	3.457,69	37.230,31	51,39%
A.P. Trento	–	–	–	–	74.201,48	17.634,30	58.536,92	78,89%
Valle d'Aosta	26.740,32	1.180,35	15.833,50	59,21%	35.461,49	1.785,68	20.468,40	57,72%
Veneto	76.205,87	4.174,65	41.437,63	54,38%	74.086,15	4.835,95	42.326,46	57,13%
The Po River Basin Authority	**88.265,85**	**4.767,22**	**49.924,72**	**56,56%**	**84.277,93**	**4.608,83**	**45.327,21**	**53,78%**

Source: CREA PB processing about FADN and SIGRIAN data.

followed by the A.P. of Trento, Veneto, and Emilia-Romagna, with values above 73,000 euros; while the lowest value is recorded in Valle d'Aosta, with values around 35,000 euros. Therefore, the turnover per worker (measured in terms of TR), which indicates the average economic value of labour productivity, shows a very high variability in the District; a variability explained by the type of cultivation and by the structure of the farms, in terms of size and work organization. In any case, in most of the Regions of the District included in the Irrigation Water Service, there is a rather high TR/WU ratio, considering that, according to ISTAT data, at national level, the value of Agricultural Production per WU in 2018 is about 44,000 euros[9].

Significant variability is found in the Added Value (AV) per WU, an indicator of labour profitability. With an average value of 45,327 euros in 2018, the highest level is found in Lombardy (about 60,000 euros), followed by the A.P. of Trento, with 58,500 euros, and then by Veneto, Emilia Romagna, and Piedmont. The lowest value is observed in Valle d'Aosta (20,500 euros). Also, in this case, in order to have a reference benchmark, it can be considered that the national average value of the AV/WU ratio, according to ISTAT data, was equal in 2018 to about 24,400 euros.

In addition, it is interesting to note that the average AV/TR ratio is around 54% in 2018; this ratio depends on the extent of the costs of raw materials and services and derives from how much value the production process adds to the raw materials used: it is structurally different depending on the crops.

Another interesting indicator is the TR/UAA ratio, which represents the economic value of land productivity. An average of 4,609 euros/ha in 2018

9. ISTAT and FADN data are not perfectly comparable, but the comparison still provides a basic benchmark.

corresponds to very differentiated values, with the highest value in the A.P. of Trento, with as much as 17,600 euros, and the lowest in Valle d'Aosta (less than 1,800 euros). In Lombardy there is a rather high value, namely 6,000 euros/ha (the highest value after the A.P. of Trento), followed by Veneto and Emilia Romagna (values above 4,000 euros/ha) and then Piedmont (3,500 euros/ha).

2.2. *Economic-structural indicators of farms using self-supply irrigation*

In analysing FADN data for agricultural use of water in self-supply irrigation, only farms falling outside the SIGRIAN LAWMs were considered. Again, the variability between the two years considered is relatively low, so the data for 2018 will be discussed in general, keeping those for 2016 as a frame of reference.

In 2018, the sample of farms using self-supply irrigation consists of 83,850 farms, distributed as follows: 29.256 in Emilia-Romagna, 19.663 in Lombardy, 30.887 in Piedmont, 1.212 in the Autonomous Province (A.P.) of Trento, 391 in Valle d'Aosta, 1.359 in Veneto, 642 in Liguria, 301 in Marche and 139 in Tuscany. In terms of numbers, Emilia-Romagna, Piedmont and Lombardy are by far the most important regions (Table 5).

Table 5 - Number of Farms in the self-supply irrigation area, years 2016 and 2018

Regions	**2016**	**2018**
Emilia Romagna	25.924	29.256
Liguria	627	642
Lombardy	22.228	19.663
Marche	227	301
Piedmont	20.954	30.887
Tuscany	184	139
A.P. Trento	280	1.212
Valle d'Aosta	342	391
Veneto	1.683	1.359
The Po River Basin Authority	**72.451**	**83.850**

Source: CREA PB processing about FADN and SIGRIAN data.

An analysis of farm Agricultural Area (Table 6) shows that in the Regions and Autonomous Province considered, it amounts to an average 25,43 hectares in 2018, compared to 24,14 hectares in 2016. The Utilized

Table 6 - Average Agricultural Area (TAA), Average Utilized Agricultural Area (UAA) and Average Irrigated Utilized Agricultural Area for Farms in the self-supply irrigation area, years 2016 and 2018

Regions	**Average Farm TAA (ha)**		**Average Farm UAA (ha)**		**Average Farm Irrigated UAA (ha)**	
	2016	**2018**	**2016**	**2018**	**2016**	**2018**
Emilia Romagna	26,32	28,35	20,22	21,03	3,37	2,93
Liguria	13,38	12,74	12,62	12,07	0,25	0,24
Lombardy	20,42	22,92	18,9	21,15	10,1	11,17
Marche	18,58	26,99	16,97	23,96	–	–
Piedmont	23,7	23,35	19,2	18,41	3,72	3,86
Tuscany	224,85	277,25	80,07	78,89	–	–
A.P. Trento	12,97	9,92	10,91	9,06	2,38	3,2
Valle d'Aosta	76,1	66,19	63,08	62,4	6,18	6,12
Veneto	19,01	28,72	16,77	25,18	9,28	11,84
The Po River Basin Authority	**24,14**	**25,43**	**19,68**	**20,21**	**5,64**	**5,33**

Source: CREA PB processing about FADN and SIGRIAN data.

Agricultural Area (UAA) is, on average, 20,21 hectares in 2018. The lowest value is recorded in the Autonomous Province of Trento, with 9,06 hectares in 2018, while the highest values are found in Tuscany with 78,89 hectares in 2018.

As expected, from a structural point of view a very diversified reality emerges from Region to Region. In particular, Liguria and the Autonomous Province of Trento have very limited average farm sizes, both in terms of Total Agricultural Area (TAA) and Utilized Agricultural Area (UAA). On the contrary, farms in Tuscany have a particularly high average size (277,25 hectares of SAT and over 78 hectares of UAA in 2018). It is important to underline that these data are probably conditioned by the small size of the sample (falling in the Po River Hydrographic District) for this Region.

Regarding the average farm size in the different Regions, the most relevant information is that about the average irrigated UAA. According to these sample data, the average irrigated area is around 5,33 hectares in 2018, which corresponds to 26,4% of the average total UAA and these values are very similar to those of 2016. While in Lombardy and Veneto the average irrigated UAA is around 50%, in Piedmont it is around 20% and in Emilia-Romagna 14%, due to both the availability of irrigation and the conformation of the territory, more or less suitable for irrigation.

These values are lower than those related to the farms that are part of LAWMs but, in any case, higher than the average values of other farms located in the same areas, as a consequence of the way the sample was designed. From the analysis of these data, it emerges that Lombardy is, on the whole, the Region that contributes the most to the total irrigated UAA.

Turning to the economic characteristics of the farms, in particular in terms of labour, the average number of Working Units (WU) per farm is just under 1,5 units, both in 2018 and 2016, with different values from Region to Region. The minimum is 1,1 WU in Liguria and Marche and the maximum is 2,3 WU in Tuscany (Tables 7 and 8).

The total revenue of the farms using self-supply irrigation is around 99 thousand euros, but with considerable fluctuations from one Region to another, ranging from 33-34 thousand euros in Liguria to 150-160 thousand euros in Veneto. In Lombardy the average value of total revenues is around 110,000 euros, in Piedmont around 95,000 euros and in Emilia-Romagna 94,000 euros.

Also, in terms of added value there are important differences: the average added value per farm is about 54 thousand euros, with a minimum for Liguria equal to 22-23 thousand, and a maximum for Veneto where, in 2018, it exceeded 84 thousand euros. In the two years analysed, the ratio of added value to total revenues is between 54 and 55%, substantially in line with the

Table 7 - Average Work Unit (WU), Average Total Revenue (TR) and Average Added Value (AV) for Farms in the self-supply irrigation area, years 2016

Regions	**Average Farm WU**	**Average Farm TR (€)**	**Average Farm AV (€)**	**AV/TR (%)**
Emilia Romagna	1,39	93.408,66	51.248,66	54,86
Liguria	1,06	33.249,77	23.170,51	69,69
Lombardy	1,48	106.553,10	54.459,22	51,11
Marche	1,10	38.492,54	25.771,52	66,95
Piedmont	1,51	97.284,88	58.370,75	60,00
Tuscany	2,34	74.871,85	52.254,85	69,79
A.P. Trento	1,25	84.202,46	50.556,27	60,04
Valle d'Aosta	2,06	67.859,46	38.939,16	57,38
Veneto	1,66	150.533,28	68.511,81	45,51
The Po River Basin Authority	**1,46**	**98.993,72**	**54.313,62**	**54,87**

Source: CREA PB processing about FADN and SIGRIAN data.

Table 8 - Average Work Unit (WU), Average Total Revenue (TR) and Average Added Value (AV) for Farms in the self-supply irrigation area, years 2018

Regions	**Average farm WU**	**Average farm TR (€)**	**Average farm AV (€)**	**AV/TR (%)**	**AV/WU (€/wu)**	**TR/UAA (€/ha)**
Emilia Romagna	1,41	94.827,21	52.316,38	55,17	37.103,82	4.509,14
Liguria	1,07	34.489,79	22.158,86	64,25	20.709,21	2.857,48
Lombardy	1,43	115.152,33	57.654,69	50,07	40.317,97	5.444,55
Marche	1,12	49.329,17	33.345,87	67,60	29.773,10	2.058,81
Piedmont	1,49	93.126,27	50.933,98	54,69	34.183,88	5.058,46
Tuscany	2,27	91.787,31	62.918,82	68,55	27.717,54	1.163,48
A.P. Trento	1,17	69.475,83	50.063,20	72,06	42.789,06	7.668,41
Valle d'Aosta	1,93	79.933,50	46.257,63	57,87	23.967,68	1.280,99
Veneto	1,62	162.839,55	84.356,56	51,80	52.071,95	6.467,02
The Po River Basin Authority	**1,44**	**99.002,30**	**53.235,70**	**53,77**	**36.969,24**	**4.898,68**

Source: CREA PB processing about FADN and SIGRIAN data.

values of farms included in the SIGRIAN LAWMs. The added value per working unit is about 37 thousand euros, which is very similar to the 2016 value but significantly below the 45 thousand euros for the farms using the Irrigation Water Service. Average revenues per hectare of UAA amounted to just under 5 thousand euros per hectare in 2018 (and slightly more in 2016), a value that is decidedly high and substantially comparable with farms located in SIGRIAN LAWMs, reflecting the high productivity of the farms in this area of Italy.

Therefore, on the whole, these are decidedly important farms, whose impact on the local and national agri-food economy is absolutely significant.

2.3. *Economic indicators of Livestock Farms*

The economic description of livestock in the Po River Basin District was carried out by selecting from the FADN sample only those with Livestock Units (LU) values higher than zero, and only for the year 2018. The analysis of the main economic indicators (Table 9) shows that in the District, the revenues per hectare of the farms with livestock are equal to about 6,896 euro, while the added value per hectare reaches 2,989 euro. These values can be explained using purchasing feed bought from other areas. The total revenue per LU is 1,451 euros per year, while the added value per LU is 629 euros per year. Considering the and data related only to the SIGRIAN LAWMs as representative of the revenue that can be obtained from all the animals bred in the Po River Basin District is a daring exercise that can be attempted to define an order of magnitude of the variables involved. According to this logic, it can be argued that the total revenue of all farms located in this area in 2018 amounts to about 8.1 billion euros and the added value to about 3.5 billion euros.

Table 9 - Average Value for Farms with Livestock Units (LU)>0 in The Po River Basin Authority, year 2018

Regions	Number of Farms	Average Farm UAA (ha)	Average Farm LU	Average Farm TR (€)	Average Farm AV
Valle d'Aosta	140	114,91	51	115.662	67.357
Piedmont	228	56,45	134	242.687	102.204
Lombardy	198	52,88	696	710.692	267.432
A.P. Trento	12	50,03	71	225.363	122.461
Veneto	78	50,54	613	609.836	312.424
Liguria	65	30,21	27	55.723	40.057
Emilia Romagna	180	54,51	264	710.667	306.217
Tuscany	15	122,21	103	291.361	220.947
Marche	7	v40,44	47	84.905	55.471
The Po River Basin Authority	**923**	**62,69**	**298**	**432.308**	**187.376**

Source: CREA PB processing about FADN and SIGRIAN data.

These values are also justified considering the high quality of the products obtained, also demonstrated by the high presence of certified products (PGI, PDO, etc.), as shown in Table 10. These certified productions – which represent 16% of the total certified productions in Italy – represent the most visible, but not unique, part of the role that breeding in the Po River Basin District has in the creation, directly or along the agri-food chains, of identity goods.

Table 10 - Certified production in the livestock sector by type and Region in The Po River Basin Authority, year 2018

Species	Type of Certification	Valle d'Aosta	Piedmont	A.P. Trento	Veneto	Liguria	Emilia Romagna	Tuscany	Marche
Cattle	Protected Geographic Indication (IGP)						1		
	Other type of certification	1	1			1	4	2	
	National Quality System	1	20	4	1	22	10	7	2
	Certified Integrated Production (Regional Quality Marks, SQNPI, Standard UNI 11233)		1						
Sheep	Protected Geographic Indication (IGP)						3		
Chickens	Other type of certification						3		
	Product life cycle (UNI EN ISO 14040 LCA)						2		
Pigs	Other type of certification						1		
The Po River Basin Authority		**2**	**22**	**4**	**1**	**23**	**24**	9	2

Source: CREA PB processing about FADN and SIGRIAN data.

Conclusions

The support of the economic analysis in drafting the WMP is fundamental to plan and program a sustainable and efficient use of water resources for agriculture. Its importance is accentuated by the possible synergy between the application of the legislation provided by the WFD and the preparation of the National Agricultural Plan, to implement the new CAP starting from 2023, as well as by the interactions with the strategies of the EU *Green Deal*.

The economic analysis is based on information collected from different databases that must be jointly used to have a comprehensive picture. The integrated use of the SIGRIAN Web-GIS platform and the data from the FADN sample survey made it possible to carry out the analysis with an innovative approach. The current structure of the FADN database does not allow to distinguish farms based on the type of irrigation use, (Irrigation Water Service or self-supply irrigation) as required by the MEA. However, the information in the SIGRIAN database filled this gap and allowed the analysis of the Po River Basin District to be completed. The main results are summarized below.

The joint use of the two databases, italian FADN and SIGRIAN, has allowed for the collection of the necessary information to carry out the socio-economic analysis and define and compare the economic-structural indicators calculated for the farms that use the two types of irrigation. It emerges that for the two years analysed, the average farm size is larger in the farms that use the irrigation water service. Because of the greater efficiency of the collective irrigation system, it is reasonable to assume that this is used preferentially when the average farm size increases.

The same trend is followed by the more strictly economic indicators. In fact, the working units required for farms included in SIGRIAN LAWMs are, on average, higher than those in farms that use self-supply irrigation. The system managed by LAWMs records higher values of total revenues and average added value for both years. The minimum values of these two indicators are found in Valle d'Aosta for Irrigation Water Service and in Liguria for self-supply irrigation; the maximum values are recorded in Lombardy and Veneto respectively. There is a similarity between average farm size, total revenues and added value, which are always higher for farms using the Irrigation Water Service.

It is therefore clear that the management of collective irrigation, although more complex considering, for example, the higher number of working units required, is preferable because of the greater efficiency demonstrated by the higher values of income and added value.

Irrigation is essential to allow the economic sustainability of farms in the Po River Basin District. This also affects dry agriculture, given the strong interrelationships existing in the affected areas between irrigated and non-irrigated crops. The reduction in the availability of water for irrigation would lead to a loss of productivity of irrigated crops and to changes in crop arrangements, with implications for the use of labour and complementarity with animal husbandry. The importance of the agri-food chain in the examined area demonstrates that considering irrigation water only for agricultural activity is rather reductive and that it is necessary to examine the issue from a broader point of view, including the socio-economic benefits generated from industrial transformation activities. Semi-intensive agriculture in areas of medium-high altitude could hardly be maintained at an adequate level of competitiveness, in absence of the pull constituted by agricultural activity in the plains and low hills. The management of a substantial part of the irrigated areas through irrigation bodies offers considerable potential in terms of efficiency in the use of the resource. The coordination in the planning of uses by individual farms practiced in these bodies could also be extended to areas where self-supply is prevalent with important expected benefits for water saving.

From a methodological point of view, the analysis carried out demonstrates the need and opportunity to focus on the coordinated development of data collection and management systems. For example, the information on the withdrawal of water in the self-supply regime and those relating to the destination of the water withdrawn and the irrigation techniques used could be enriched. Furthermore, in the FADN database the volumes of water used for irrigation are often recorded on a farm scale (due to the methods of measurement) while the crops and relative yields are reported based on the individual plot, thus making it impossible to calculate unit water consumption.

In addition, the evaluation of positive externalities could complement the economic analysis of agro-livestock production if the necessary data were systematically included in the SIGRIAN database.

While irrigation – especially in the Po River Basin District – plays a central role in the production of wealth from agricultural production and the agri-food supply chains, the challenges posed by climate change and the green turning point of the European Union require the continuous strengthening and refinement of the methods for monitoring and managing the use of irrigation resources. To face these challenges, a better understanding is needed of context and the ways in which it reacts to the constraints and incentives posed by policies. It is certainly worth investing a portion of the public resources dedicated to water resource management to the production of statistical data that is as reliable and as complete and homogeneous as possible.

In the future, the introduction of new variables concerning irrigation systems in the FADN database and monitoring of information being constantly added to the SIGRIAN database on the one hand, and the joint use of these data on the other, would guarantee a complete and shared knowledge of the management of water resources in agriculture. This is an important concept both at the national and international level and includes social and economic sustainability as well as environmental and agronomic aspects. This could lead to the creation of a system for monitoring the sustainability of farms and evaluating the performance of sustainable and certified food systems.

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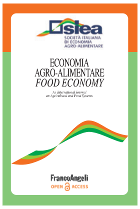
Economia agro-alimentare /
Food Economy

An International Journal on Agricultural and Food Systems

Vol. 23, Iss. 3, Art. 14, pp. 1-17 - ISSN 1126-1668 - ISSNe 1972-4802
DOI: 10.3280/ecag2021oa12775



Organic and conventional farms in the Basilicata region: a comparison of structural and economic variables using FADN data

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Abstract

Organic farming in Italy is growing fast thanks to an increased focus on environmental sustainability and consumer demand thus challenging the farmers to create new working models and territorial systems.

Organic land in Basilicata is more than 21% of the regional UAA, an area that has more than doubled in size since 2015. This study compares Lucanian organic farming systems with conventional farming systems and their economic benefits and is based on 2019 FADN data made up of 24% organic farms. This study could help regional policy makers to design guidelines for the 2021-2027 programming period reinforcing the green

growth strategy. In fact, agricultural policy continues to focus on environmental themes (Green Deal and Farm to fork), proposing new challenges to agricultural businesses who take advantage of the competitive advantages of new models and territorial systems.

Article info

Type:
Article
Submitted:
15/05/2021
Accepted:
23/09/2021
Available online:
12/01/2022

JEL codes:
Q10, Q12, Q18

Keywords:
FADN
Organic
Sustainability
Regional agriculture

Managing Editor:
Lucia Briamonte,
Luca Cesaro,
Alfonso Scardera

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Introduction

Organic farming is an integral part of the new and ambitious green growth strategy for Europe, details of which are outlined in the United Nations Sustainable Development Goals and the 2030 Agenda.

In Italy, the incidence of organic land reached 15.8% of the national Utilised Agricultural Area (UAA) in 2019, which places it well above the EU average (7.5%) (SINAB, 2020).

In Basilicata, the number of organic farms and dedicated agricultural area have also grown over the last few years, particularly in 2019.

This study aims to analyse the structural characteristics and economic results of organic farms and their peculiarities and compares them to conventional farms using the Lucanian Farm Accountancy Data Network (FADN), the most important source of statistics available in the European Union (Cesaro & Marongiu, 2013: 38).

The results could help regional policy makers design guidelines for the 2023-2027 programming period whilst also responding to consumer demand.

There is a substantial amount of literature analysing the economic aspects of organic agriculture (Röös *et al.*, 2018: 13), most of which concentrates on the comparative evaluation of the economic results of organic and non-organic farms at case study level or homogeneous farm samples selected on the basis of structural and/or productive variables (Abitabile & Arzeni, 2013: 33). There are also in-depth qualitative studies on specific farm cases and sector-specific thematic studies identifying the strengths of the organic sector within the territory and its networks and outline development paths based on the basic principles of organic farming (D'Oronzio & Pascarelli, 2016a: 10). Some Basilicata case studies highlight elements of a network and also social and cultural innovation (local identity, landscape and behavioral stakeholder models) elements of considerable importance (Sturla & Vigano, 2019: 15; D'Oronzio & Pascarelli, 2016b: 576).

Many studies have concluded that organic farms are frequently more profitable than conventional farms thanks to government price premiums and support from European Union (EU) policies.

Organic production profitability varies considerably between products, regions and individual farming methods and the reasons for buying organic food vary, including health and nutritional concerns, perceived superior taste, environmental and animal welfare concerns and distrust in conventional food production (Hoffmann and Wivstad, 2015; Lakner & Breustedt, 2017).

Consumer demand for organic products has risen dramatically, with global sales increasing more than threefold since the turn of the century with substantial financial benefits for the industry (Reganold & Wachter, 2016).

Some European countries, for example, are currently witnessing a boom in sales of organic foods and in 2019, Denmark, Switzerland and Austria had the highest consumption of organic products per capita ("The world of organic agriculture", 2021).

Reasons for buying organic food vary from health and nutritional benefits, taste, environmental and animal welfare concerns to a distrust in conventional food production (Hoffmann & Wivstad, 2015: 978; Abitabile *et al.*, 2015), and can justify the higher premium (Zander, 2011: 11). The recent approval of the European Green Growth Strategy for Europe (the Green Deal) and the Farm to Fork strategy has further strengthened organic farming and offers development opportunities in European rural areas. As a result, organic farming will be able to create new jobs and attract young farmers by generating sustainable territorial development models.

1. Basilicata organic farms

Basilicata has exceptional natural ecosystems and agro-ecosystems within two national parks, two regional parks and many protected areas that form part of the Natura 2000 network and thanks to financing and community support, the practice of organic farming has so far been successful (De Vivo & D'Oronzio, 2012: 263).

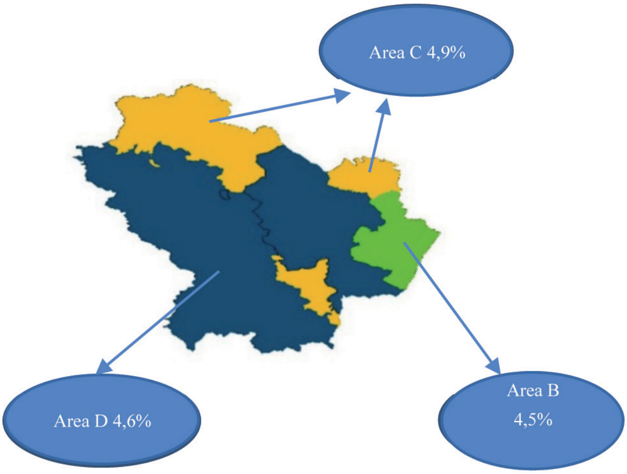
Organic land is more than 21% of the entire Basilicata UAA, an area that has more than doubled in size since 2015 (49,904 ha) (Sinab, 2017; 2020). According to the organic production method, over 103,234 hectares were cultivated in Basilicata in 2019 with a large proportion of organic land (over 52%) dedicated to crops (36% cereals and 16% fodder), reflecting the region's needs, fruit and vegetables account for 5.2% and the same for olive farming.

Data from Basilicata's organic farms register shows that organic farms are on average larger than conventional farms, the average organic farm land is 43.1 ha compared to an average conventional farm land of about 12.6 ha (ISTAT SPA, 2016). Organic farms are mainly single farms, one third of which are managed by men 50% of whom are between 40 and 60 years old. The territorial distribution sees a prevalence of farms located in the province of Matera (about 60% in total), with a substantial uniformity in the three rural areas that characterize the region in the 2014-2020 programming period, namely area B, C and D[1]. These areas approximately correspond to

1. Rural areas with development problems (D), including rural municipalities in the southern hills and mountains with lower population density. Intermediate rural areas relating to hillside municipalities with higher population density. Rural areas with intensive agriculture (B) including municipalities located in lowlands.

the metapontino plain (B), Matera, the Vulture-Alto Bradano and Agri hills (C), and the remaining Lucanian mountains (D).

Figure 1 - Organic farms percentage per rural area



In 2020, there were 2,414 organic farms in Lucania, a slight increase of 2.3%, compared to 2019, although the number of producers is growing, their numbers are still very low.

The regional organic sector, which mainly consists of a network of small businesses and farms, uses "short supply chain" logic, a social phenomenon that has opened up new frontiers and posed commercial challenges to both the producer and the consumer whilst, simultaneously, educating the consumer on variety, quality and cultivation methods (De Vivo & D'Oronzio, 2012: 269).

In addition, and as a result of consumer demand, the organic farming world in Basilicata is growing thanks to a whole range of products available in farms, restaurants and canteens which often cater to a clientele who are not strictly "healthy" yet are mindful of the product origin and authenticity. (De Vivo & D'Oronzio, 2012: 269; Sturla, 2019: 72).

There are two organic producer consortiums in Basilicata, ConProBio and FIRAB who contribute to strengthening regional organic businesses through guidance, knowledge and support. ConProBio, based in Metaponto, Basilicata, is a consortium of more than fifty organic and biodynamic producers and supports businesses and consortiums in the Puglia and Calabria regions, whils also supporting participates in regional and national research projects.

Both FIRAB and AIAB Basilicata are carrying out some interesting research on the dissemination of the principles of agroecology and organic farming in the region.

Basilicata has invested considerable financial resources through the Rural Development Programs (RDP) in the last programming cycles to encourage farmers to change their farming methods in favour of systems more respectful of the environment, biodiversity and food quality. Measure 11 of the 2014-2020 "Organic farming" RDP has allocated around 13% of the financial resources to support farmers in the introduction and maintenance of organic farming. In addition, Basilicata Rural Policy is financing "organic districts" in the Alto Bradano inner area.

Finally, the establishment of the regional organic farms register, the financing of producer consortiums and initiatives aimed at encouraging the use of organic products in schools demonstrates the focus of the Region on issues which could develop by the next Organic Action Plan from 2022.

2. Methodology and materials

The analysis was conducted on data from FADN samples in 2019, a year that saw a high number of farms registered regionally. The sample amounts to 374 farms, 24% of which were organic farms, covering about 36% of the UAA. On a national level, organic farms are on a par at 6.2% of total businesses, 21% of the UAA. The percentage of organic farms in total is greater than the FADN sample. The FADN samples consist of professional market oriented farms, whose standard output[2] is over 8,000 euros.

The FADN data sample can be attributed to the presence of agricultural businesses oriented towards more profitable markets with an output of more than 8.000 €. FADN organic farms cover 68.7 ha of land, however, organic registered farms cover 21 ha of land.

The analysis is carried out on two sub-samples (organic and conventional farms) differentiated by gender and age group, structural characteristics and economic indicators. For structural characteristics, the analysis will focus on average farm size, working units and their availability in terms of UAA, livestock units (LU) and machine hours per unit.

The following indicators were considered for the economic analysis to identify the economic flow of farms. Average and standard deviations are shown for each indicator.

2. The standard production is the sum of the values of the standard productions of the individual production activities, multiplied by the number of hectares and/or animals present on the farm under analysis.

Table 1 - List of economic indicators

		Avarage	Standard deviations
Total Revenue	Value of sales and services, changes in stocks, own consumption, public aid from CMO, and revenues from complementary activities	106,711.80	88,680.86
Current costs	Given by the sum of expenses incurred for the purchase of non-corporate inputs, other miscellaneous expenses and third-party services	39,746.00	35,286.80
Farm Net Value Added (FNVA)	As between gross saleable production (GVA) and current costs	66,966.00	53,014.35
Depreciation	Given by depreciation and provisions	7,818.00	6,703.15
Net product	As the difference between FNVA and multi-year costs and expresses the gross operating result net of fixed costs	59,418.00	47,458.60
Operating Income (OI)	Economic result of the characteristic management of the agricultural enterprise, which includes all costs and revenues generated by production processes and by active and passive services related to agricultural activities	42,421.00	37,564.84
Non-CMO public aid	CAP Pillar II aid	3,562.00	3,693.41
Farm Net Income (FNI)	The overall economic result that, compared to OI, also includes costs and revenues originating from activities not considered typically agricultural, the so-called extra-characteristic management	45,160.00	40,095.59
Labour Factor	Labor units (1 UL corrisponds to 2200 hours)	2.19	1.45

Source: our elaboration on FADN (2019).

On the whole, the standard deviation did not vary from the average, highlighting a relatively low dispersion of data.

These indicators are related to Total Revenue which include the value of sales and services, changes in stock, own consumption, public aid from (CMO), and revenues from complementary activities.

3. Result and discussion

The territorial distribution of organic farms by altitude shows a concentration in the hills, 16% higher than conventional farms and 17% higher than the corresponding UAA. The percentages do not differ in the plains, while conventional farms prevail in the mountains. This distribution is similar for Italian FADN organic farms in the period 2016-2019 (National Rural Network, 2021).

Table 2 - FADN distribution by altitude (%)

	Organic		**Conventional**	
	% farms	**% UAA**	**% farms**	**% UAA**
Mountain	22%	32%	38%	47%
Hill	60%	64%	44%	47%
Plain	18%	4%	18%	6%
Total	**100%**	**100%**	**100%**	**100%**

Source: our elaboration on FADN (2019).

There are a higher number of organic farms managed by women and people under 40 (Table 3), highlighting the organic farms propensity towards multifunctionality, data supported by increased revenue from related activities compared to total farm revenue which is almost double that of a conventional farm (Table 5).

Table 3 - Farms managed by women and young people (%)

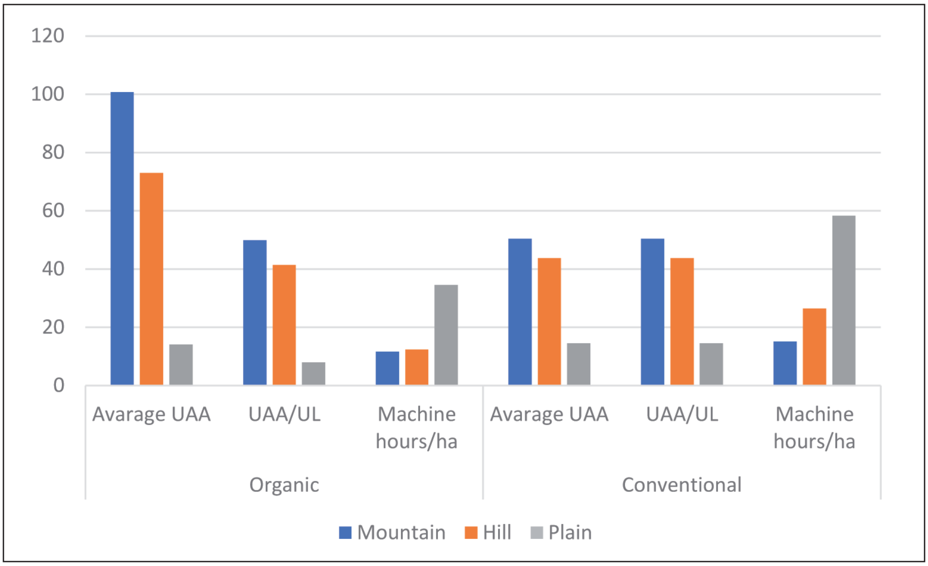
	Organic	**Conventional**
Farms managed by women	29%	26%
Farms managed by young people < 40 years	33%	14%
of which women	30%	34%

Source: our elaboration on FADN (2019).

Organic farms have a higher average UAA in line with FADN data (NRR, Bioreport, 2019). The difference between the UAA is particularly significant in the mountains where organic farms have a UAA (100.8 ha) that is double conventional farms (50.4 ha). There are less differences between organic and conventional farms, particularly in the mountains and hills, if we compare the surface area to the number of working units.

Organic farming reveals a higher number of machine hours per hectare of UAA in all the higher altitude areas. However, this indicator is 40% in the plains for organic farms, highlighting a less intensive use of the land and the adoption of agronomic practices aimed at soil conservation.

Figure 2 - Structural characteristic



Source: our elaboration on FADN (2019).

The number of livestock units (LU) for the average number of farms and UAA, is lower in organic farms than conventional farms in all altitude zones/areas. This result indicates an increase in livestock farming, also confirmed by the relationship between LU and agricultural work units, which, for organic units presents as a lower value.

Work units are predominantly family based in the sub-samples and in mountains and hills. However, the work unit in the plains favour wage earners, with a percentage of family labour almost doubling in organic farming. As a result, fruit and vegetable production in lowland agriculture requires a huge wage labour commitment, particularly for harvesting.

Balance sheet indicators show a similar situation between the two sub-samples. Organic operating income[3] is 44.4% of total, six percentage points higher than conventional farms. The figure could be attributed to the added

3. Operating income relates to revenues to production processes and services linked to purely agricultural activities.

Table 4 - Comparison of structural characteristics - Average farm data

		Organic	Conventional
Mountain	LU (nr)	28,3	49,0
	LU/UL (nr)	14,0	28,7
	LU/UAA (nr)	0,3	1,0
	FLU/UL (%)	76,0	82,0
Hill	LU (nr)	25,9	23,7
	LU/UL (nr)	14,7	15,0
	LU/UAA (nr)	0,4	0,5
	FLU/UL (%)	63,0	62,0
Plain	LU (nr)	0,0	18,8
	LU/UL (nr)	0,0	4,4
	LU/UAA (nr)	0,0	1,3
	FLU/UL (%)	58,0	26,0

Source: our elaboration on FADN (2019).

pressure of related activities and to the lower impact of current costs linked to the reduction in use of products such as fertilizers, pesticides, etc, a gap which is highlighted in operating income. The net income was influenced by EU aid from the second pillar of the CAP, in fact, the Rural Development Programmes (RDP) provided specific support to organic farming through measure 11 "Organic farming" which was aimed at encouraging the introduction and maintenance of organic practices. The impact of financial aid on total revenue is low for the FADN sample, the average is 9%. In 2019, the net organic and conventional farm income did not change significantly between 2016 and 2019 (National Rural Network, 2021).

The improved economic performance of organic farms is linked to their considerable physical size: organic net income is 78% for conventional farms, despite increased aid.

An analysis of economic data by altitude does not show variations in the percentage of the various items of total revenue apart from aid, with consequential impact on net income.

An analysis of net farm income for type of farming[4] shows improved results for organic farms and an increased gap for farms specializing in plants, then livestock and finally for mixed farming.

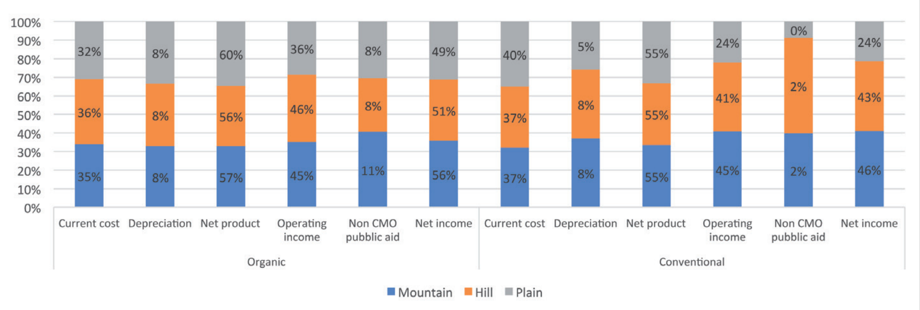
4. The Type of Farming is defined in terms of the relative importance of the different activities on the farm, measured as a proportion of each activity's Standard Output on the farm's total Standard Output.

Table 5 - Unit economic results for farm

	Organic		Conventional	
	Euro	**Incidence on total revenues**	**Euro**	**Incidence on total revenues**
Total revenue	106.149,4		106.899,3	
of which from related activities	7.013,5	6,6%	3.853,4	3,6%
Current cost	37.823,8	35,6%	40.386,7	37,8%
Added value	68.325,6	64,4%	66.512,6	62,2%
Depreciation	8.184,5	7,7%	7.696,3	7,2%
Net product	60.141,0	56,7%	58.816,3	55,0%
Operating income	47.162,6	44,4%	40.840,7	38,2%
Non CMO public aid	9.245,3	8,7%	1.667,8	1,6%
Net income	54.928,2	51,7%	41.904,1	39,2%

Source: our elaboration on FADN (2019).

Figure 3 - Budget items on total revenue per altitude zone



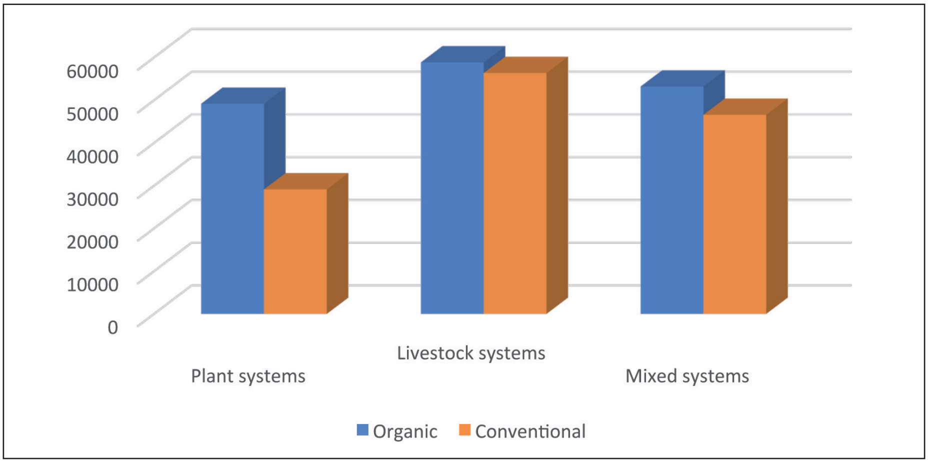
Source: our elaboration on FADN (2019).

The organic FADN farms mainly specialize in cereals, oilseeds and protein crops.

Table 6 shows organic farms have a higher net income per hectare than conventional farms which is linked to an increased impact from related activities, EU aid and total income, a fact attributable to higher prices, underlining the increasing consumer demand for quality organic products.

However, not all the organic farms in the sample receive aid under the second pillar of the CAP, RDP Measure 11, only 86%, which may be linked

Figure 4 - Net farm income by type of farming



Source: our elaboration on FADN (2019).

Table 6 - Economic result of cereals, oilseeds and protein crop farms

	Organic		Conventional	
	Euro	**Incidence on total revenues**	**Euro**	**Incidence on total revenues**
Total revenue	84.277		51.033	
of which from related activities	9.516	11,3%	903	1,8%
Current cost	32.638	38,7%	22.286	43,7%
Added value	51.639	61,3%	28.748	56,3%
Depreciation	8.137	9,7%	3.391	6,6%
Net product	45.273	53,7%	25.357	49,7%
Operating income	38.273	45,4%	21.794	42,7%
Non CMO public aid	10.806	12,8%	2.078	4,1%
Net income	46.263	54,9%	23.285	45,6%

Source: our elaboration on FADN (2019).

to a choice made by the farmer, who is discouraged by the lack of financial assistance or the administrative burden required to access support.

There has been a growing focus on reducing the use of synthetic products in agriculture to increase farming sustainability, improve product quality and reduce the negative impact on the environment.

ISTAT statistics shows a reduction of 7.8% in the quantity of fertilizers used in Italy between 2017 and 2019, a trend confirmed by Assofertilizzanti with a 5% reduction in fertilizer sales for the same period. Farmers use of lower dosages and more efficient products and a reduction in hectares in the production of cereals has also impacted these statistics.

Furthermore, Basilicata reduced its fertilizer use to around 21.5% in 2019[5], less than the rest of Italy.

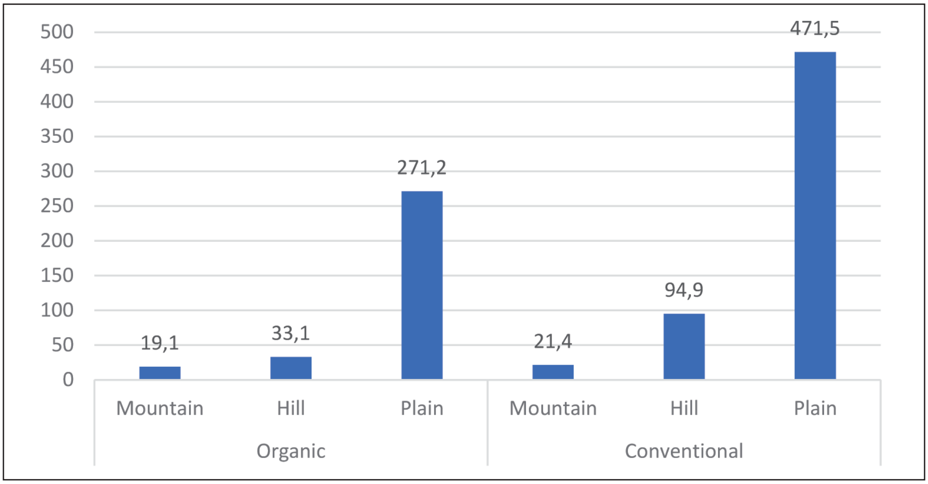
It is well noted that organic farming is a production method that does not use synthetic chemicals or pesticides which improve soil characteristics, and respects life forms and useful organisms. Slow releasing organic or mineral substances are used to fertilize and treat soils. It has been proved that organic farming increases the carbon content in the soil and is a useful measure to reduce greenhouse gases (Drinkwater *et al*., 1998; Liebig *et al*., 1999; Niggli *et al*., 2009; Wells *et al*., 2000; Coderoni & Bonati, 2013). Organic farming aims to provide high quality food with minimal environmental impacts, making production eco-sustainable. The release of CO_2 is certainly one of the most important of this type of agriculture. Consequently, several studies have revealed how the conversion to organic farming improves the soil content of organic carbon on average by 2.2%, while conventional systems did not promote this change or there was no significant change (Leifeld *et al*., 2010). A study by Andreas Gattinger (Gattinger *et al*., 2012) of the Research Institute for Organic Agriculture predicts that in the next few years organic farming can reduce CO_2 emissions caused by agriculture by 23% in Europe and by 36% in the United States. Furthermore, organically managed soils have more biomass and greater stability and biodiversity than conventional managed soils and therefore tend to be able to retain water, porosity and stability, representing an important form of protection in the event of drought and floods.

Only 66% of organic FADN's use fertilizers, compared to 81% of conventional farms. The amount of fertilizers distributed per hectare of UAA significantly varies between altimetrical areas, reaching peaks in the lowlands, where fruit and vegetable production is abundant. The organic farms present lower values in all three altimetries, with significant differences in the plains (–42.5%) and in the hills (–65.%), where the practice of green manure is widespread with positive effects on the conservation of soil fertility.

There are no significant disparities in the quantity of pesticides distributed, either in Italy or in Basilicata between 2017 and 2019. 54% of organic farms and 64% of conventional farms used pesticides. Chemical pesticides were not used in organic farming, in their place, plant preparations were used to effectively combat pests and are not dangerous to humans or the

5. In 2017 there was a reduction of about 4% in the UAA (our calculations based on ISTAT data).

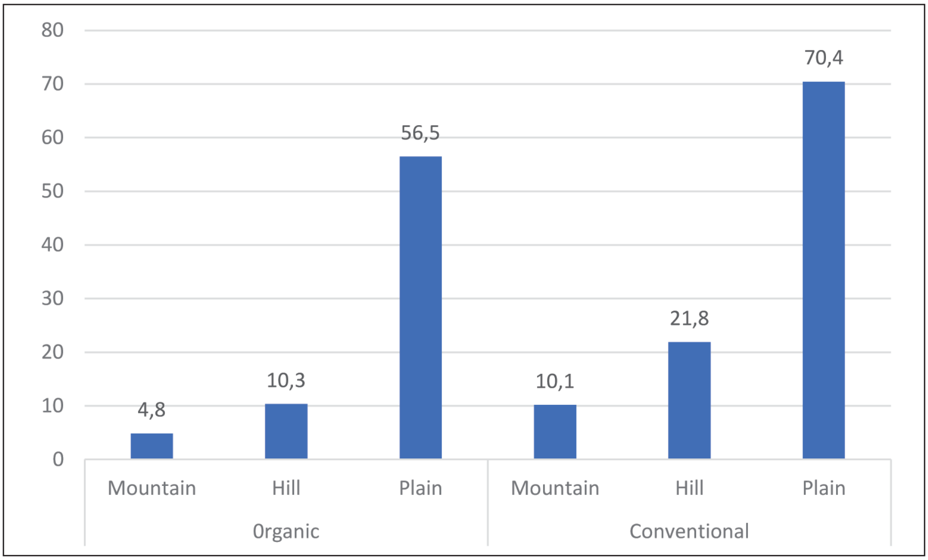
Figure 5 - Value of fertilizers distributed per hectare of UAA (€)



Source: our elaboration on FADN (2019).

environment. Insects, mites, nematodes are also useful to combat and limit populations of insects and/or pest mites in a targeted and specific way.

Figure 6 - Value of pesticides distributed per hectare of UAA (€)



Source: our elaboration on FADN (2019).

The value of pesticides used by organic farms per hectare of land is significantly lower than conventional farms in all three altitude zones as the cost of the products used by organic farmers is on average higher, a lower quantity is distributed.

Conclusions

This study began with a need to analyse the financial and environmental benefits of organic farming that in Basilicata is growing due to the increasing focus on environmental sustainability, biodiversity conservation and food quality by consumers. In some regional areas, organic farms are organizing in the "Organic district" concentrating on a new common specific development path. The organic farming market is also continuously evolving through the innovative farms ability to take diversified paths (Canali *et al.*, 2020: 7) to increase and stabilize their income and improve the marketing strategies to promote their products (BIOREPORT, 2019).

Experience and knowledge influence farmer behaviour with some organic farms adopting technological innovations already in use in conventional agriculture, paving the way for profitability and efficiency. The sharing of knowledge between farmers is important in improving management skills and management practices. The adoption of new technology is becoming easier and less costly as the it becomes more available thanks to the rural development policies which have encouraged the transfer of knowledge.

FADN results present a positive image of organic farms, from structural characteristics to economic performance. They are more dynamic with an increased presence of women and young people, and focus on multifuncionality in the market place (Gargano *et al.*, 2021: 5). An additional important element is the lack of assistance from PAC regarding total revenue which is challenging the farmers to work smarter.

The Lucanian results stress the importance of effective policies for knowledge sharing in how to improve yields and productivity in organic farming. These positive elements are part of the green growth strategy for Europe the "Green Deal", an integral part of the 2030 Agenda and the United Nations Sustainable Development Goals approved in December 2019. The main proposals concern the use of sustainable practices in agriculture, such as organic farming and a series of initiatives to foster a circular economy and to tackle biodiversity loss.

Finally, on the 19th of April the European Commission approved the new Action Plan for Organic Agriculture for the period 2021-2027, which was in line with the Farm to Fork Strategy.

Hence the need to continue the research by developing ad hoc surveys useful for regional policy makers. The qualitative-quantitative analysis could also be developed with ad-hoc investigations using consistent FADN data over time, to understand the peculiarities of these farms and investigate the motivation of the new organic farming methods and processes adopted on social and territorial common paths.

The measurement of the reduction of CO_2 emissions and use of water in organic farms compared to conventional farms could be an important line of research for FADN through a revision of its methodology.

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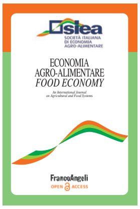
Economia agro-alimentare /
Food Economy

An International Journal on Agricultural and Food Systems

Vol. 23, Iss. 3, Art. 15, pp. 1-24 - ISSN 1126-1668 - ISSNe 1972-4802
DOI: 10.3280/ecag3-oa12777



Investments financing at farm level: A regional assessment using FADN data

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Abstract

This article presents the results of an ex-ante evaluation exercise on the financial instruments adopted under the rural development policy. Using FADN data, during a ten-year time span, the study estimates the investments and their financial covertures made by a sample of farms in the Abruzzo region. The balance sheets of the farms were analysed in order to quantify the investments made by the farms in one year and the related financial coverage. The main results show that the propensity to invest is, on average, of 0.27 and it varies according to the characteristics of the farms; while on average 90% of farm investment value is self-financed. These results provided some interesting policy implications, highlighting either or both, a latent need for farms for external financial funds and/or an ineffective financial management of the business activity.

Article info

Type:
Article
Submitted:
14/05/2021
Accepted:
11/10/2021
Available online:
12/01/2022

JEL codes:
R58, O16, Q14

Keywords:
Rural development programme
Financial instruments
Farms investments, investment funding
Propensity to invest

Managing Editor:
Lucia Briamonte,
Luca Cesaro,
Alfonso Scardera

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Introduction

This article presents the main results of an ex-ante evaluation on the public support for investments, available under the Rural Development Programme (RDP) and implemented using financial instruments (FIs).

The term FIs refers to various measures of support for investments which, differently from the traditional straight grants, provide the repayment by the beneficiary of the sums received as a support of their investments. These measures concern: interest subsidies, subsidised loans, loan guarantees, etc.

The activation and management of these interventions takes place with the participation of various public and private actors: on the one hand, the European Commission, Member States, Regions that adopt the laws, regulations and administrative provisions to ensure their proper functioning; on the other hand, financial institutions such as banks, credit consortia or other institutions that physically manage the funds (guarantee and credit, in particular) for the disbursement of contributions to beneficiaries who request them. The reasoning behind these interventions is to face the more or less manifested difficulties that farms encounter in accessing private external financing to support their investments, and more specifically to help beneficiaries to find the coverage of the private share of those investments which are co-financed by the European Agricultural Fund for Rural Development (EAFRD).

In the context of rural development policies, the use of FIs is not new, the so-called financial engineering instruments were already programmed during the period 2000-2006 and substantially confirmed in the subsequent programming periods.

In the present programming period of the European Structural and Investment Funds these instruments have been strengthened and represent support measures to achieve one or more specific objectives of the European Union (Reg. (EU) no. 37-46). This because, according to the European Commission (EC, 2014), FIs can represent a more efficient method of disbursement of aid to the beneficiary than traditional forms of non-repayable support. They guarantee greater efficiency in the use of public resources, especially in cases of economically and financially important projects but with low returns and long repayment periods, and they help to improving access to finance by supporting the working capital of firms with medium-long term loans. These theses are also found in various researches and articles (among others, Wishlade & Michie, 2014, 2017; D'Auria & Guido, 2016; Núñez-Ferrer *et al.*, 2017).

During the various programming periods the FIs were largely unsuccessful, generally motivated by issues linked to both the supply and demand side of such policies (Licciardo, 2020). On the supply side, these measures have not been widely adopted by the Managing Authorities of rural policies, for example in 2007-2013 only 14 RDPs in 7 Member States included them in their programmes, allocating a total amount of resources of 531 million euro, which represents only 0.3% of the total EAFRD budget (Tropea and de Carvalho, 2016). On the demand side, there was a restricted use of such interventions by the potential beneficiaries to finance their investments.

In this regard, an assessment of the European Court of Auditors highlighted that the scarce recourse of that measures by the beneficiaries of the RDPs would be due to erroneous budget forecasts by the individual managing authorities, which made inaccurate ex-ante assessments, allocating an excessive amount of funding with respect to the potential needs of the RDPs beneficiaries (ECA, 2015; 2016).

Based on what has been described and considering the methodological indications of the European Commission (2014, 2015), several evaluation studies (Kollatz-Ahnen, 2014; Guido *et al.*, 2015; Nucera *et al.*, 2018; Fi-compass, 2018) have focused on analysing the characteristics of credit demand from farms, highlighting the real difficulties encountered by them in accessing external funds for their investments and/or to cover the private share of co-financed investments.

About the frictions that farms could face in accessing bank credit, many analyses evidenced difficulties for farms trying to highlight the possible underlying reasons (Carillo, 2013, 2014, 2015; Kim and Katchova, 2020; Guido *et al.*, 2015; Nucera *et al.*, 2018). The authors generally argued that as consequences of the new credit access rules, imposed by the Basel III Accords, the banks reduced the volume of loans to farms and their exposure to agricultural loans. More specifically, the Italian debate on the agricultural credit for investment (medium-long credits) verifies its reduction (Carillo, 2014, 2015) and raises the problem of farm projects which, despite receiving public support, fail to meet the selection criteria of banks and consequently fail to access credit for their co-financing and implementation (Guido *et al.*, 2015).

This is the background of the evaluation exercise proposed here, which has been carried out by an independent evaluator (Institute of Industrial Relations Studies - ISRI) for the Abruzzo Region RDP 2014-2020. The main objective of the work was to analyse the potential interest of RDP beneficiaries in FIs, starting from the estimated number of regional farms and their characteristics, the possible difficulties encountered in accessing bank credit, highlighting the probable motivations which could explain the frictions present on the local credit market. The exercise was conducted, first through the reconstruction of the preferences expressed by regional farms for the various forms of financing to support their investments and subsequently, with a survey, through the analysis of the possible reasons explaining the failure of farms to access at bank lending to finance their investments. This last part of the analysis is not illustrated in this article.

The study was conducted through the Farm Accountancy Data Network (FADN), utilising data of a sample of more than 500 farms, which operate in the Abruzzo region. Through the analysis of the farm balance sheets over a period of ten years, the differences between one year and the consecutive year were calculated for each asset and liabilities items, to evidence the changes in fixed assets and the capital and financial components. The objective of analysis was to estimate at the regional level, the size and the characteristics of farms investments and how farms have financed them.

The rest of article was structured as follows. The first section describes the data and methodology used, while the second one illustrates and discusses the results. The last section concludes by making some considerations on the strengths and weaknesses of using data from official statistics, such as FADN data, as a part of the evaluation of the rural development policies.

1. Materials and methods

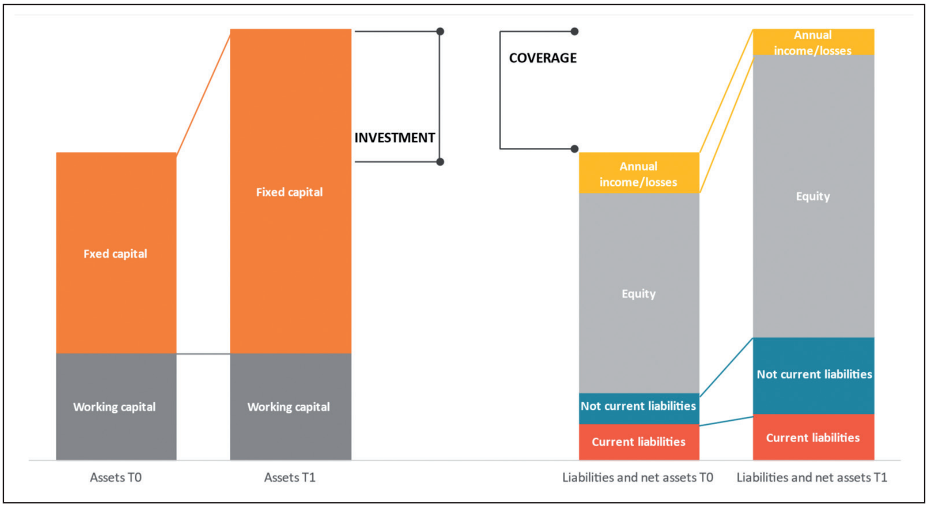
The study here proposed aimed at exploring a sample of regional farms in order to assess their propensity to invest and the prevailing ways to finance their investments. The analysis was based on the computation of the changes in the financial statements components of the farms, that occurred between an accounting year and the next one. The data used come from the regional FADN, taking as a reference the period between 2008 and 2018. The FADN sample relating the Abruzzo region consists annually of over 500 farms that have been statistically designed to consider the main typologies of regional population of farms. To proceed with the comparison of the balance sheets of two consecutive years, only farms present in the sample for at least two years were included in the panel, then reaching a total number of 1,153 farms. The balance sheets of year *n* and year *n-1* of the same farm were then compared by calculating the differences even on multiple pairs of balances belonged to the same farm, when the farm was present for more than two years or for the whole analysed period. In this way, an overall number of 4,164 balance sheets was compared.

From a methodological point of view, the comparison between the balance sheets allowed us to calculate the differences between the various items of assets and liabilities, through which to estimate both the amount and type of investments made by the farm and the ways in which they have been funded. According to the definition of Begg *et al.* (1991), in this work the investment represents «the purchase of new durable capital goods by the firm» and so it has been estimated by the amount of positive[1] changes in the capital stock. So, through the changes that occurred during the year in the fixed assets present in active of the balance sheet, we identified the new acquisitions, consisting of land, plantations, buildings, machines, equipment and so on, and estimated the investments made by the farm in the year.

The calculation of the changes in the passive balance components on the other hand, allowed us to estimate the most probable ways utilised by the farm to finance their investments, for example through the reduction of farm liquidity, the increase in short or long-term debts, the increase of equity, etc.

The logic of the analysis is summarized in Figure 1, while Table 1 shows and describes the balance sheet items which were compared.

Figure 1 - Conceptual scheme of the comparison methodology



Source: authors' own elaboration.

According to the previous schemes, the increase in active components that we associate to the investments can be balanced by:

- a decrease in other items of fixed or working capital (for example through the sale of land or stocks in the warehouse),

1. The farm's decision could also lead to a reduction in capital, thus causing a negative variation. The FADN data does not allow us to establish whether the investment made is intended to replace an existing capital, which is, among other things, not relevant for the purposes of this study.

- an increase in profit or a reduction in losses compared to the previous year.
- a decrease in deferred or immediate liquidity (for example by using an availability accumulated in the current account),
- an increase in short or medium and long term debts,
- an increase in equity (for example retaining the profit from the previous year, or to a contribution of new capital by the owner or shareholders),
- an increase (but it would be better to say a smaller decrease, since it is always negative) of the entrepreneur's self-consumption and withdrawals, which occurs to the extent that the owner renounces the withdrawals that he makes every year for his own livelihood, becoming a self-financing from private resources.

Table 1 - Structure of the balance sheet in the FADN survey

Assets	**Liabilities**
Fixed	Debts
– Land and buildings	– Current liabilities
– Agricultural land	– Operating debts
– Forest land	– Not current liabilities
– Plantations	– Medium-long term debts
– Buildings	– Severance indemnities provision
– Intangible assets	– Other creating provisions
Fixed working capital	Equity
– Machineries and equipment	– Total net capital
– Livestock	– Net capital
– Concessions, licences and trademarks	– Entrepreneur contributions
– Furnitures and furnishings	– Capital reserves
– Current	– Retained earnings
– Current assets	– Accumulated other comprehensive loss
Inventories	Self-consumption and abductions of entrepreneur
– Liquid assets	– Self-consumption
– Operating credits	– Abductions
– Cash and cash equivalent	– Annual income
Total Assets	Total liabilities and equity

Source: authors' own elaboration on FADN methodology.

We emphasise that, for an amount of investments less than 20 thousand euros, the analysis of the balance sheets collected through the FADN survey does not allow us to identify significant differentials in the balance sheet liability items which could be reasonably linked to the specific financing requirement. For this reason, we only have considered investments exceeding this amount, in order to verify their possible financial coverage.

As this regard, we are still aware that the ordinary management of a farm – even a small one – determines a large part of the movements in the balance sheet and that, consequently, attributing specific movements to the financing used for investments is a probabilistic exercise. It is however clear that the greater the size of the investment the more the other changes of opposite sign are connected to it.

Finally, once we have computed for each farm the investments and the financial sources used, we were able to estimate a sort of "propensity to invest" for regional farms. This propensity was estimated using a Probit model, accounting for farms heterogeneity and for time. Specifically, the Y variable of the model is a dichotomous variable that takes value 1 if farm made investment and 0 otherwise. Two categorical variables, which represent the economic size and the productive specialization of farms, as regressors are used to take account the effects of farm characteristics that could condition the likelihood to invest of farm. The years in which investments were made are included, to take into consideration the contingent influence on the propensity of farm to invest. Model is formalising as follows:

$$\Pr(Y = 1|X = x) = \beta_0 + \beta_1 X$$

where

- $\Pr(Y)$ is the probability that farm invests (the first model) or the probability that farm uses external financing (the second model);
- $\beta_0, \beta_{1,\ldots}\beta_n$ are coefficients which we are interested in;
- X is a vector of x_i which are categorical variables representing the characteristics of the farms and the years.

The variable used as regressors are relative to a measure of Economic Size (ES) and the Type of Farming (TF) that are used for the classification of FADN sample. To represent the ES we use a categorical variable, representing five classes of ES, built on the basis of the standard output (SO) of farm. SO is a measure of the value of total production, calculated starting from the average monetary value of the agricultural output at farm-gate price, in euro per hectare or per head of livestock. These variables are described in Table 2.

Table 2 - Variables and number of observations

Accounting year	**Frequency**	**Percentage**	**Cumulated**
2009	504	12,1	12,1
2010	353	8,48	20,58
2011	407	9,77	30,36
2012	284	6,82	37,18
2013	384	9,22	46,4
2014	319	7,66	54,06
2015	445	10,69	64,75
2016	480	11,53	76,27
2017	487	11,7	87,97
2018	501	12,03	100,00
Economic size (classes of standard output in euros)			
Small (>= 4,000; < 25,000)	689	16,55	16,55
Medium-small (> =25,000; < 50,000)	1.051	25,24	41,79
Medium (> =50,000; < 100,000)	999	23,99	65,78
Medium-large (> =100,000; < 500,000)	1.161	27,88	93,66
Large (> =500,000)	264	6,34	100,00
Type of farm			
Field crops	1.177	28,27	28,27
Horticulture and floriculture	89	2,14	30,4
Permanent crops	1.532	36,79	67,2
Grazing livestock	532	12,78	79,97
Granivores	96	2,31	82,28
Mixed crops	453	10,88	93,16
Mixed livestock	86	2,07	95,22
Mixed (crops and livestock)	199	4,78	100,00
Total	4.164	100,00	

Source: authors' own elaboration on FADN data.

2. Results

Typologies of investments and propensity to invest

The reduction of sample only to farms which are present in two or more consecutive years, could affect the representativeness assured by the full FADN sample. In order to check if the selection problem arises from this reduction and to measure the extent of the probable distortion of the sub-sample used, we ran the statistical test of Kolmogorov-Smirnov (K-S). The non-parametrical K-S' Test tests a null hypothesis of a common population distribution given samples from two groups. Using the yearly distribution of "type of farming" variable, we tested the equality of distributions resulting from the two samples: the selected sub-sample, that is what we used for analyses, and the full FADN sample, designed to be representative of the regional farms population.

Results of test showed that the combined K-S statistic is relevant for our hypothesis of equal distributions between samples, while we reject the null hypothesis for the year 2012, due to the low p-value (.004), showing a distortion of the sample representativeness only for this year (see Table 3).

Table 3 - Two-sample Kolmogorov-Smirnov test for equality of distribution functions: type of farming annual distributions

Accounting year	**D**	**p-value**
2009	0,02	1,00
2010	0,04	0,95
2011	0,01	1,00
2012	0,13	0,00
2013	0,04	0,83
2014	0,05	0,65
2015	0,01	1,00
2016	0,02	1,00
2017	0,06	0,40
2018	0,03	0,99

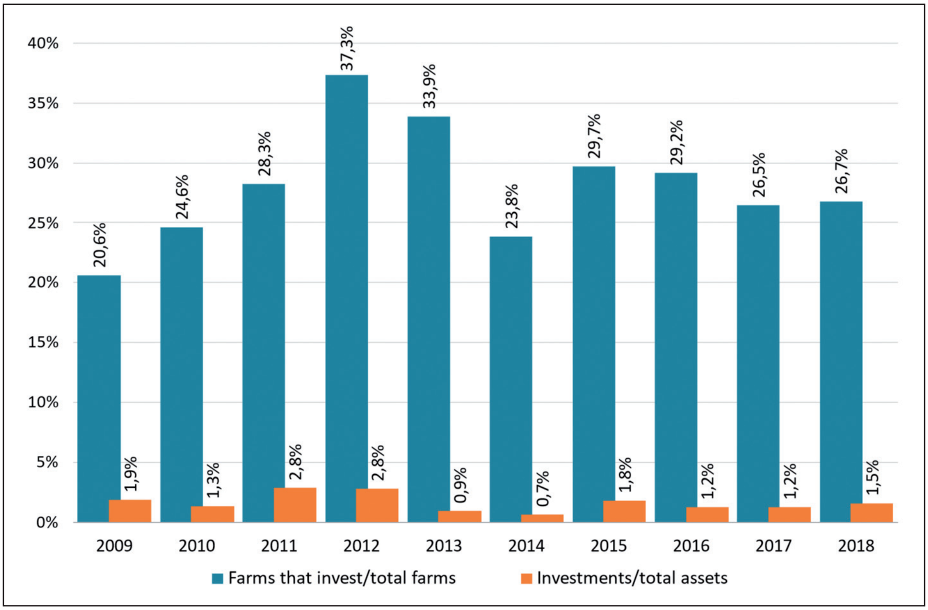
Source: authors' own elaboration based on regional FADN data.

The analysis of balance sheets showed that of among the 4,164 pairs of financial statements observed, there were approximately 1,400 cases in which one or more items of asset had increased in value. Then, about one third of the balances showed that an investment and its amount were, on average, of about 16,000 euros.

Looking at the data by farm and year, it is possible to highlight that, among the 1,153 farms included in the sample, about one half of them made an investment every two years and that this investment is, on average, about 20,000 euros per farm and per year.

On the yearly basis, a considerable variability is observed in the predisposition to invest of farms. For example the ratio between the value of the investment and that of the of total asset is, on average, of 2.8% in 2011 and 2012, but it decreases to 0.7% in 2014. Similarly, the portion of farms that make an investment over the total farms also varies significantly, moving from 20% in 2009 to 37% in 2012 (Figure 2).

Figure 2 - Fixed investments in agricultural farms 'assets (in %)



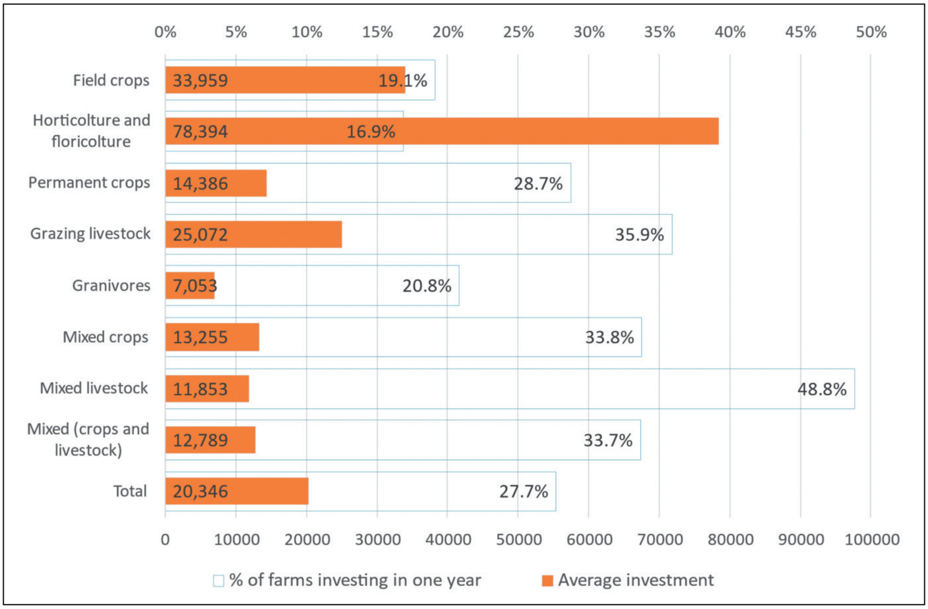
Source: authors' own elaboration based on regional FADN data.

It is also evident that the extent to which farms are involved, not varying over the years in proportion to the overall intensity of the investment effort, implies a high variability of the average annual investment, which in fact varies, in the years considered, from a minimum of 10 thousand euros (in 2013) to a maximum of 32 thousand euros (in 2011). We should highlight that the significance of variables related to different years may be influenced by the transition from the rural development programming period of 2007-2013 to the one of 2014-2020. In this sense, the lack of significance of the year 2014 might be indeed due to the traditional lag in calls' preparation and technical procedures for assessing financing requests. In addition, during the years 2017-2019 the investments behaviour might be affected by relevant state aids related to earthquake recovery funds.

The description of farms characteristics associated with the various amounts and types of investments allow us to illustrate the underlying determinants of farm choices.

As regard the TF it should be noted that, on average, the highest investments concern farms specialized in horticulture and floriculture, with a value of about 80,000 euros (Figure 3), followed by farms specialized in arable crops (34,000 euros) and grazing livestock farms (25,000). All the other TFs have values below the average (equal to about 20,000 euros).

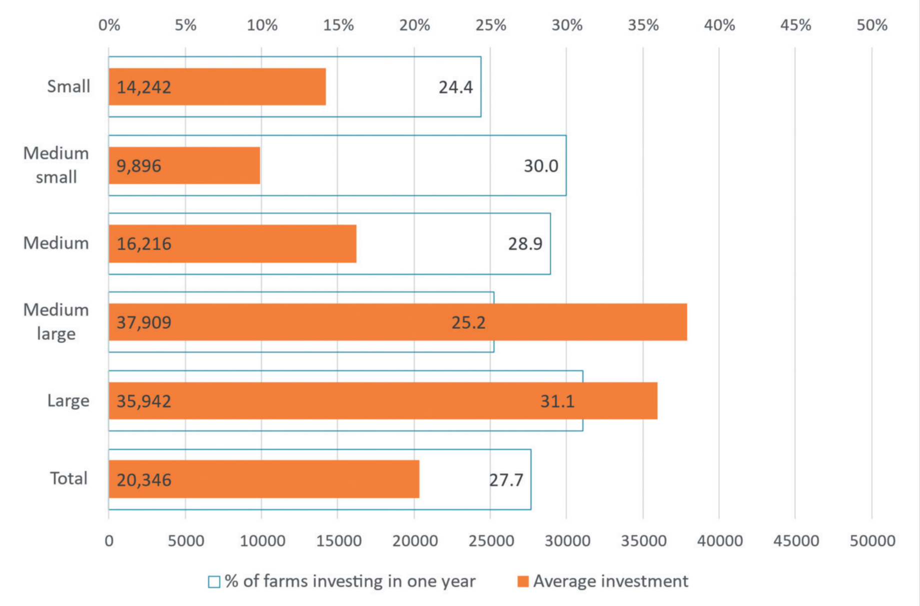
Figure 3 - Average annual investments and type of farms (data in value and %)



Source: authors' own elaboration based on regional FADN data.

As it is logical to expect, the economic size of the farm is another determinant of the propensity to invest conditioning the average value of the investment. However, by descriptive analysis it emerges that the percentage of farms investing in a given year does not vary significantly between the different classes of ES; while the average investment amount for medium-large and large farms, coherently with the expectations, is substantially greater than the average investment of small farms (Figure 4). It should be noted that the new investments in relative terms could be low due to the high value of the land in the denominator, or else it could appear high in the case of farm with leased land.

Figure 4 - Average annual investments and economic size of farms (data in value and %)



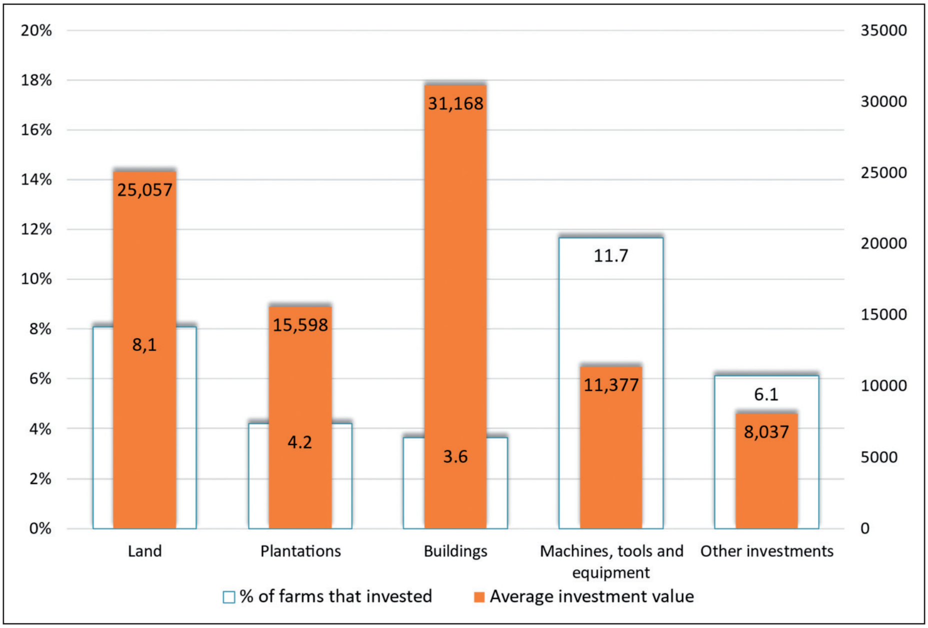
Source: authors' own elaboration based on regional FADN data.

Taking into account the typologies of investments, it can be seen that more frequently they concern the purchase of machines, tools and equipment, with a frequency of 12%, and an average value of approximately 11,000 euros (Figure 5). A higher frequency than average is also evident for investments in land, with about 8% which, of course, are averagely more costly than other categories (25,000 euros). The highest average values are however investments in buildings, exceeding 31,000 euros, while the frequency of such investments is the lowest compared to the others (3.6%).

Looking at the distribution of values associated with investments, it is possible to highlight that the percentage of investments that are above

100,000 euros in the case of buildings and manufactured is 10%, while in the case of machines, tools and equipment it is below 2% (Figure 6). We would like to underline that low investments do not necessarily imply a low endowment of machinery or other fixed capital, given that the farms analysed could have hired machinery or other assets that do not appear in the balance sheet.

Figure 5 - Average annual investments and type of investments (data in value and %)

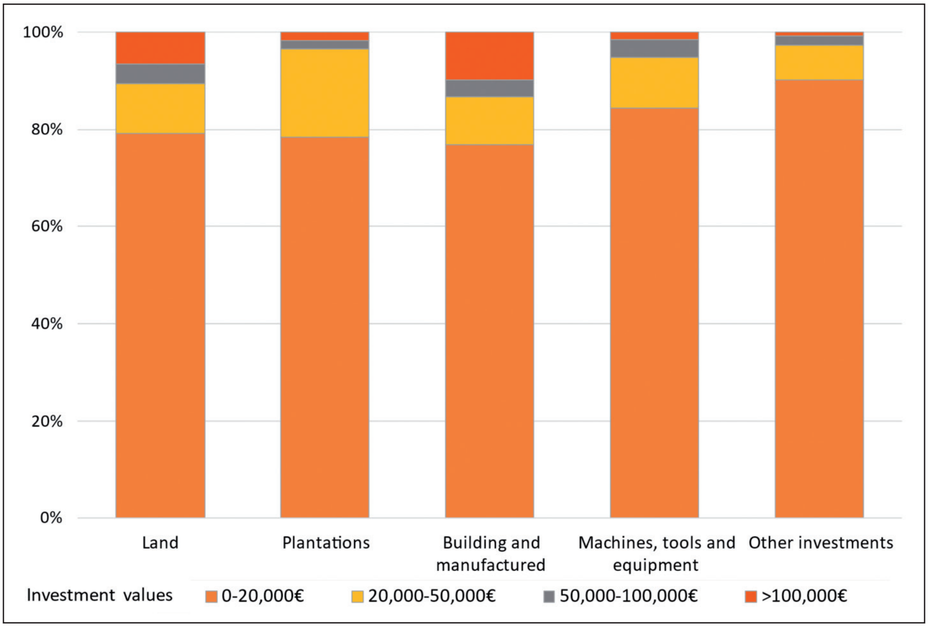


Source: authors' own elaboration based on regional FADN data.

As mentioned in the paragraph on methods, by utilizing the investment data calculated for each farm and using a Probit model, we estimated the likelihood of farms to invest by farms characteristics and times in which investments are made. The results of the model are shown in the following table (Table 4).

To illustrate this point, we can first of all see that the model fits well: the likelihood ratio chi-square of 157.38 with a p-value of 0.0000 tells us that our model as a whole is statistically significant, that is, it fits significantly better than a model with no predictors. The column two of Table 3 shows the

Figure 6 - Investment size by type (in %)



Source: authors' own elaboration based on regional FADN data.

coefficients associates with each mode assumed by the categorical variables, while the stars indicate the significance of associated p-values, so we can see that all predictors are statistically significant, although with different levels. Therefore, our results show evidence of a significant propensity change of farms over time, and in relation to their specialization and economic size.

More in details, as regard to the ES, results show that for each one unit increase in the rank, the z-score increases (see column 2 of Table 3). As for the various TFs, we can see that all the coefficients are positive and significant, except those that are associated to the arable crops and granivores, which have negative signs although not significant. In particular, the coefficient is relatively high for the livestock farms (both herbivores and mixed), while permanent crops shows the lowest coefficient. Finally, we can observe that the years in which the investment is made have a positive effect respect to the base year, increasing the z-score. However, the years that determine a greater increase in the propensity to invest are 2012 and 2013.

Relating to the coefficients estimates, we must emphasise that while the sign of the coefficient gives the direction of the effect, their magnitudes are in units of the standard-deviation of the errors, so it is not the marginal effect.

Table 4 - Probit regression results

Accounting years	**Coefficient**	**P-values**
2009	0	(.)
2010	0.14	(0.14)
2011	0.28**	(0.00)
2012	0.51***	(0.00)
2013	0.45***	(0.00)
2014	0.13	(0.21)
2015	0.32***	(0.00)
2016	0.32***	(0.00)
2017	0.24**	(0.01)
2018	0.26**	(0.00)
Economic size (classes of standard output in euros)		
Small (>= 4,000; < 25,000)	0.18**	(0.01)
Medium-small (> =25,000; < 50,000)	0.10	(0.16)
Medium (> =50,000; < 100,000)	0.16*	(0.02)
Medium-large (> =100,000; < 500,000)	0.38***	(0.00)
Type of farms		
Field crops	0	(.)
Horticulture and floriculture	–0.11	(0.50)
Permanent crops	0.29***	(0.00)
Grazing livestock	0.51***	(0.00)
Granivores	–0.14	(0.39)
Mixed crops	0.48***	(0.00)
Mixed livestock	0.85***	(0.00)
Mixed (crops and livestock)	0.48***	(0.00)
Constant	–1.26***	(0.00)

Observations =	4,164
LR chi^2 (20) =	157.38
Prob > chi^2 =	0.00
Pseudo R2 =	0.03

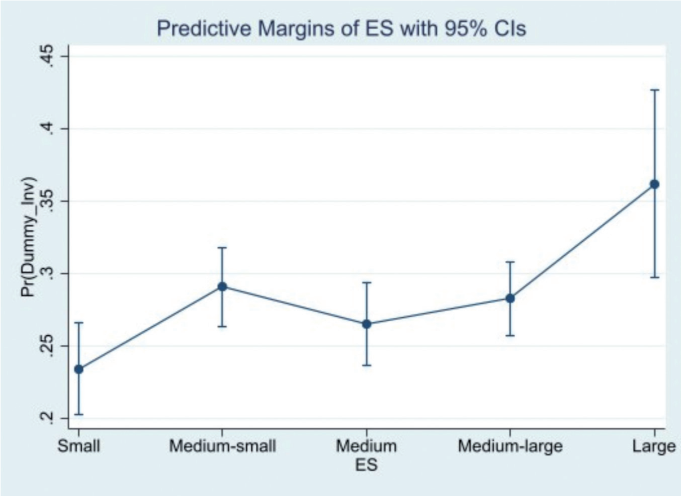
* $p<0.05$; ** $p<0.01$; *** $p<0.001$.

Source: authors' own elaboration based on FADN data.

More interestingly, we can analyse the margins of response for probabilities and linear predictions, reported in the following figures, which inform us on the partial effects on the "propensity to invest" for each factor variable, holding all other variables in the model at their means.

In Figure 7, we can see that being "small farms" makes the probability of farm to invest of 0.23, while being a "large farm" makes a probability of 0.36. On the other side, a medium sized farm has the smallest probability to invest (0.26).

Figure 7 - Margins of Economic Size



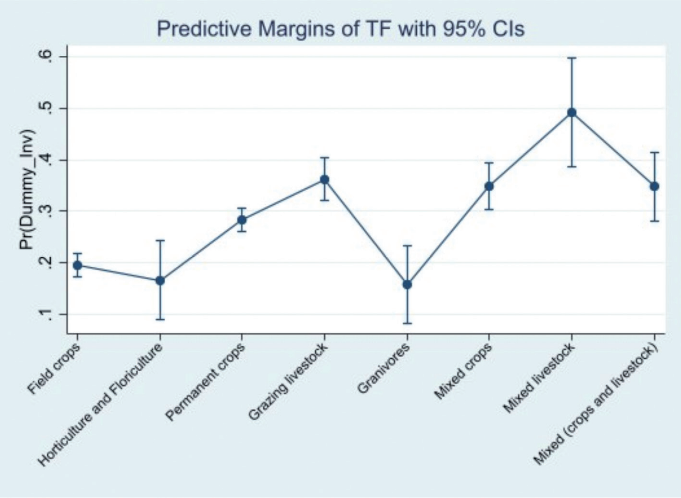
Source: authors' own elaboration based on regional FADN data.

Also belonging to different TF determines a dissimilar probability to invest for the farms (see Figure 8). The lowest probability is associated with granivorous and horticultural-floricultural, respectively of 0.15 and 0.16; while the highest are associated with Mixed farms (0.49 and 0.35) and with Grazing livestock (0.36).

At this regard, we point out that what emerged by model is in contrast with the results of descriptive analysis, where it was highlighted that the granivores and horticulture farms had the highest propensity to invest. The use of a multivariate model, allowing us to evaluate the coefficients of net variation of the coefficients associated with other variables, gives us a more correct evaluation of the different propensities of the farms.

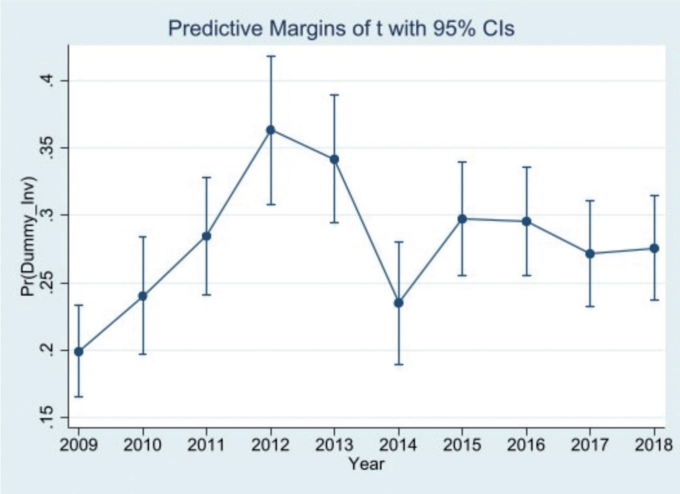
Finally, we can see that, the years in which the probability of farm to invest reaches the highest values are 2012 and 2013, all other things being equal (Figure 9).

Figure 8 - Margins of type of farm



Source: authors' own elaboration based on regional FADN data.

Figure 9 - Margins of time



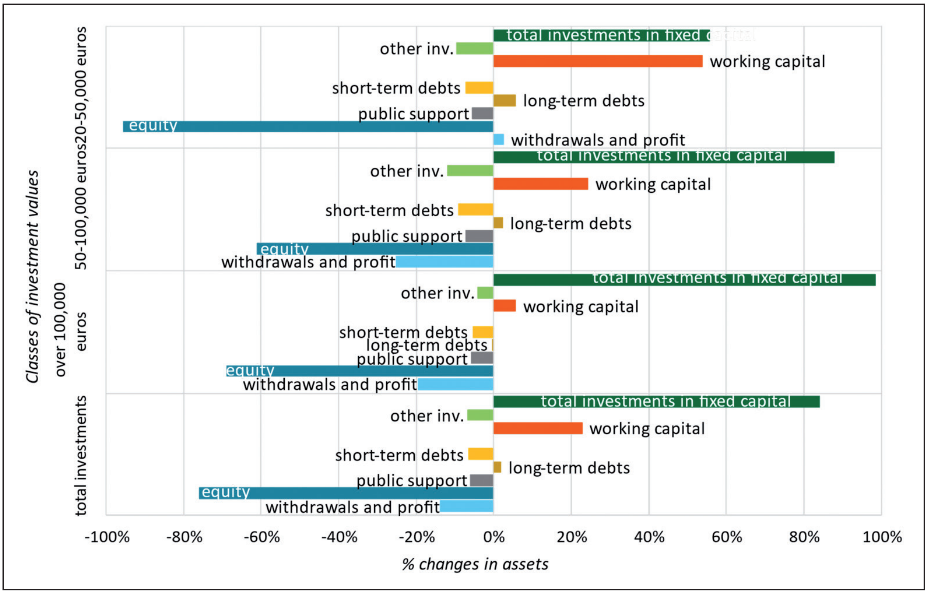
Source: authors' own elaboration based on regional FADN data.

The sources of financial baking

The variations in the financial statements, which correspond to an investment of at least 20,000 euro, have been identified and represented graphically as a percentage of the total change in assets (see Figure 10)[2].

In the selected years, there is a significant fluctuation in the balance sheet which is determined by the observed fixed investment (highlighted in the graph by a dark green bar). The greater the value of the investment, the greatest the observed variation: in the case of investments of over 100 thousand euros, almost 100% of the variation depends on the investment itself (see Figure 10). When the value of the fixed investment does not reach 100% of the variation, it means that further, independent increases in the balance sheet have taken place: for example, it can be observed that, when there are investments between 20 and 50 thousand euros, the positive variations in working capital are almost equivalent.

Figure 10 - Changes in assets by investment size



Source: authors' own elaboration based on regional FADN data.

2. These variations are represented as a percentage of the total change in assets, in positive values in the case of assets (i.e. investments themselves, other changes in fixed assets, working capital) and in negative values in the case of liabilities (i.e. debts, capital grants, equity, self-consumption and profit).

The analysis shows that, in general, the main item of compensation for investments is represented by an increase in net capital which is greater than the value of the investment if the latter is less than 50 thousand euros, while for investments higher than this amount, net capital covers 50-60% of investment value. In addition, for investments that are larger in size, there is also a significant contribution from self-consumption and profit, which means that, in the year of the investment, the owner uses a large part of the profit he has earned in the previous year to cover investments.

On the other hand, the coverage of public capital transfers is very low, about 6% of the total change in assets. This occurrence may be due to the late reception of public support compared to the time the investment was made.

The overall contribution to the financing of short-term debts is also of 6%, while the contribution of medium and long-term debts has an insignificant percentage in the sample of farms considered.

The coverage through short-term debts assumes non-negligible values both in the case of investments in buildings and manufactured goods, which are those with a higher average amount, and in the case of investments in machinery, tools and equipment, which show smaller investments.

For these two types of investment (see Figure 11), the contribution of capital aid is more significant, whereas it is very modest for investments in land.

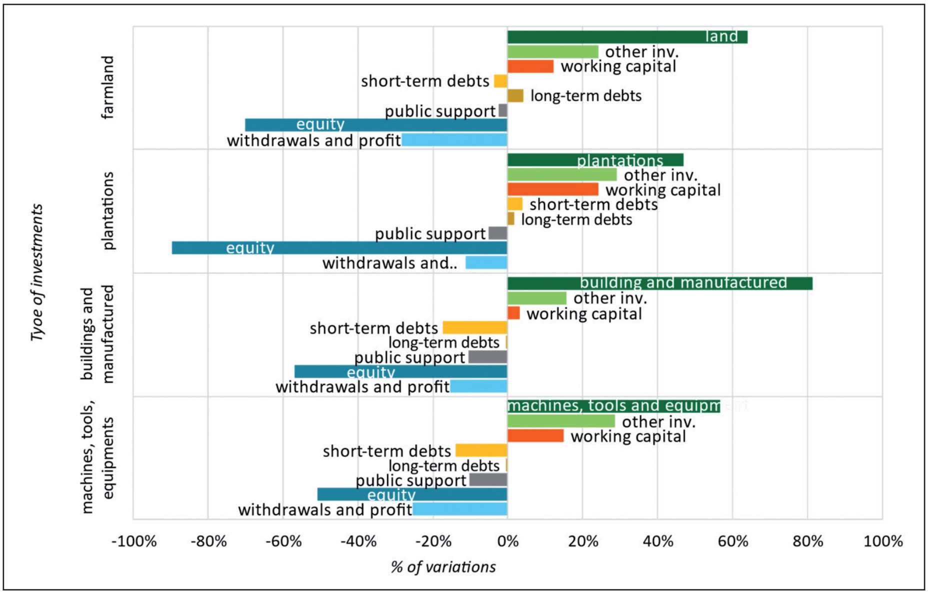
Another aspect we emphasise relating to the different types of investments by years is that the plantations and in machinery, tools and equipment are contextual to a further 30% of increases in other asset items, due probably to complementary investments.

Summarising, the analysis carried out on the balance sheets of the farms in the FADN sample can help us to understand some of the mechanisms for financing investments in agriculture, while it fails to capture the sources of financing.

In particular, it can be seen that investments are covered almost entirely by own capital and financial sources. In fact, increases in equity capital covered on average 76% of the changes in assets, and self-consumption and profit covered a further 14% of investments. However, FADN balance sheets does not provide information on the nature of these capital equity injections (e.g. the entrepreneur's personal loans, including bank loans) which balance the investments. Moreover, the almost total absence of medium to long-term debts in the farm balance sheets suggests that any loans needed by the activity are taken out personally by the respective owners.

What we can say is that 14% (average figure) covered by changes in self-consumption and profit is self-financing, while 76% linked to changes in net capital may come, to an undetermined extent, from bank or other loans through the farmer.

Figure 11 - Changes in assets by type of investment



Source: authors' own elaboration based on regional FADN data.

3. Conclusions

The objective of the study carried out in this article was to estimate the sources of financing for investments that farms use most frequently. To do this, we proposed an analytical approach based on a panel of data, coming from the FADN sample of the Abruzzo region. More in detail, our investigation considered the information related to the balance sheet of the farms in the period from 2008 to 2018.

This analysis allowed us to estimate the amount of average investments made by regional farms and the sources of coverage used for them.

Indeed the statistical analysis performed over a significant time horizon was developed with respect to yearly current investments' value, while the real values would have been more appropriate when a comparison among years is discussed referring to a long period. However our analysis is mainly based on the variations in the value of the assets of a single farm from one year to the next one, and, since in FADN the values of capitals are reported at the historical cost, the variations observed are certainly not derived from the revaluation of assets. Furthermore, for greater caution, in analysing the financial sources used to cover the investments, we do not consider the changes in the assets below 20,000 euro.

The main results show a high variability of the average investments and of the propensity to invest of farms, which can be associated with farm characteristics (economic size and type of farm). We have also shown that in almost all cases farms use equity capital to finance their investments. It is important to consider that the high use of equity to finance investments could be partly made of private financial advances of future investment subsidies, for which the authority's authorization has already been obtained, but the subsidy not released yet.

Such a low recourse to external financing may be due either to an ineffective financial management of the farm (i.e. as it does not adequately exploit the positive effects deriving from the so-called "financial leverage" that would increase its Return on Equity (ROE)), and/or it may be caused by a real difficulty of the farms to receive external financial funds. In fact, the low financial leverage could be explained by the higher cost of borrowing external financing rather than the return on investment (ROI). This would highlight a latent need for public interventions to support investments also through financial instruments, which are aimed at reducing the cost of bank loans (for example contributions on interest rates, provision of collaterals, etc.). To reinforce this last hypothesis we can refer to other studies (Carillo, 2014, 2015, 2017; Guido *et al.*, 2015) which highlighted difficulties of Italian farms in the access to bank loans. This argument suggests the need for policy interventions to facilitate the relationship between farms and lenders.

We would finally emphasise the importance of using statistical data (such as those from the FADN) for public policy evaluation, highlighting what we consider to be the strengths and weaknesses of utilising these sources.

Strengths can be related to the fact that these sources have statistical robustness in sampling, accuracy in data collection methodology and database archiving, allowing to have information over a long period of time and containing a lot of information on the structural characteristics of farms.

Weaknesses may be mainly related to the difficulty to identify the group of beneficiaries (actual or potential), and to make counterfactual evaluative comparisons between "treated" and "untreated" groups in order to estimate policy impacts.

Therefore, microdata from statistical sources (FADN or similar accounting data) can be very useful in structuring the evaluation background, both to better target the necessary ad hoc surveys of actual beneficiaries and to enrich the final considerations of the evaluation itself.

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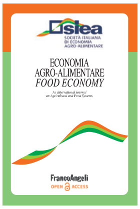
Economia agro-alimentare /
Food Economy

An International Journal on Agricultural and Food Systems

Vol. 23, Iss. 3, Art. 16, pp. 1-20 - ISSN 1126-1668 - ISSNe 1972-4802
DOI: 10.3280/ecag3-oa12778



The Role of Neighborhood Effects on Investing Dairy Farms

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Abstract

For the traditionally small-scaled Swiss agriculture, large economies of scale exist in dairy farming. Farm expansion is typically linked to a barn investment, but the opportunities for expanding the necessary acreage are limited. To enable an investing farm to expand its acreage, neighboring farms must shrink or phase out. Hence, the question arises how neighboring farms affect investing farms. To address this farm management question, we used a set of Farm Accountancy Data Network data and government data on subsidized projects. We combined this dataset with agricultural census data to assess the concentration of agricultural land as well as the number of subsidized investments within the municipality of an investing farm. By means of random-effects models for agricultural income per family working unit on the one side and herd size change on the other, we found two effects of neighborhood effects. A high number of subsidized projects and a high concentration of land (Gini coefficient) limited the growth in herd size due to scarcity of available land. At the same time, neighborhood positively influenced the management, leading to a higher agricultural income per family working unit. The results illustrate that an extension of the Farm Accountancy Data Network data, which in itself is extensive, can further help to address specific research questions.

Article info

Type:
Article
Submitted:
27/04/2021
Accepted:
10/10/2021
Available online:
12/01/2022

JEL codes:
Q12, D22, M21

Keywords:
FADN
Neighborhood effects
Farm economics
Dairy farming
Investment

Managing Editor:
Lucia Briamonte,
Luca Cesaro,
Alfonso Scardera

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1. Background

With 27 dairy cows, Swiss dairy farms hold less than half of the average number of dairy cows per farm, as compared with dairy farms in Germany, France and Italy (Hemme, 2017). Moving towards a larger enterprise by means of an investment might hold considerable advantages for Swiss dairy farmers: Besides economies of scale applying to labor (Schick & Hartmann, 2005), the necessary amount of investment varies considerably for different herd sizes of Swiss dairy farms (Gazzarin and Hilty, 2002). Compared with an investment for 30 dairy cows, investment costs per cow declined by almost 30% for a capacity of 70 cows. An even more prominent case for a potential investment is the labor-saving effect by changing from a stanchion to a free-stall barn (Schick & Hartmann, 2005). Usually, the switch between these two systems occurs with farm investments and can therefore be seen as substitution of labor through capital. In Switzerland, this change occurred relatively late. Whereas in 2003 about two thirds of all dairy cows in Switzerland were still held in stanchion barns, this applied to only one third in 2013 (Meyre, 2016). Investments in new dairy barns contributed substantially to this change.

In Switzerland, dairy farms willing to invest in a new dairy barn are eligible for interest-free investment credits supplied by cantonal institutions (at province level). Besides being interest free, these investment credits allow the farms to exceed the borrowing limit set by law (Bundesrat, 1991). The cantonal institutions are required by law to examine the business plan in order to ensure that investing farms are capable of repaying the loan for the investment (Bundesrat, 1998b). Competition with business enterprises other than farming must be considered by authorities. However, similarly to other countries, no guidelines exist that introduce constraints on the spatial distribution on interest-free investment credits. Hence, competition for spatially limited resources is not considered by the cantonal institutions in the evaluation of the future success of dairy farm investments.

Investments resulting in larger dairy barns could lead to the expectation of economies of scale even in the short term, due to increased labor productivity (Schick & Hartmann, 2005) and since economies of scale usually apply also to small farms (Chavas, 2001). However, Kramer *et al.* (2019a) showed that Swiss dairy farms investing in new barns need several years, i.e., a larger time span than strictly short term, to reattain their pre-investment profitability.

Animal husbandry is closely linked to acreage, i.e., available land, because of feed production and manure utilization. Dairy farming is linked even more strongly to the corresponding agricultural land because roughage is low in energy density and not as suitable for transportation as are concentrates. In addition, farmers must keep the number of livestock units below a certain level per acreage to obtain direct payments from the Swiss government (Bundesrat, 1998a). Feinerman and Peerlings (2005) found that farm buildings and acreage act as complementary inputs. They state, that farmers knowing land will become available in the future, exceed the point of optimal investment. Due to the fact that investments in larger dairy barns are related to land, a limited resource, we have to deal with a potential neighborhood effect.

According to Manski's seminal work (1993), a so-called neighborhood effect exists if the propensity of an individual to behave in a specific way depends on the prevalence of this behavior within a reference group to which the individual belongs. Justification of neighborhood effects is often given psychologically or sociologically by relating the behavior of an individual to an intrinsic desire to follow others, to interdependencies of constraints a group of individuals face, or to interdependencies in information transmission (Durlauf, 2004). Manski (1993) finds that a valid model to test the existence of neighborhood effects depends on the knowledge of how the reference group of an individual is built. In the current study, the reference group is clear to describe: Looking at the technological and managerial shift related to dairy barn investments, one might hypothesize an influence of the behavior of those with whom the investor has frequent contact (Rice, 2015), the neighboring and potentially investing dairy farmers. This group of farmers faces the same institutional environment of limited acreage in a given municipality, i.e., there exists an interdependency of constraints. Personal interaction of neighboring farms with information exchange helps farmers to anticipate future strategies of neighboring farms and their demand for acreage. Hence, there are also interdependencies of information transmission.

The existence and consequences of neighborhood effects in agriculture have been studied in the farm management literature. Schmidtner *et al.* (2012) analyzed the positive effects of neighboring farms on conversion to organic farming in Germany. Mack (2012) examined spatial influences on the conversion to suckler cow production and concluded that peer effects exist as long as a production process is new and therefore associated with uncertainty; as uncertainty declines, peer effects decline. Sauer and Zilberman (2012) found that Northern European farms adopting a milking robot early on, positively influenced farms in their neighborhood to follow their example. The authors attributed those spill-over effects to knowledge transfer and imitation by other farmers. It has also been shown in the literature that the spatial limitation of land markets leads to interference of decisions of neighboring farms. Because of this spatial limitation, strategies of neighboring farms are mutually dependent (Margarian, 2010). For example, Feinerman and Peerlings (2005) derived a model to analyze the influence of the uncertain availability of agricultural land on the investment decision of Dutch dairy farmers, but their results were inconclusive. Hence, although the link between investments in a new technology and spill-over effects to neighbors has been made in the literature, to our knowledge there is no empirical study that links an agricultural investment and neighborhood effects related to the availability of agricultural land. Investing farms rely on the success of their new barn since it ties up a considerable share of future cash flow, constricts future scope of action and therefore determines the strategy for the subsequent years. Therefore, the information whether a neighborhood effect is present and how it affects the success of their investment is important to farmers and hence a pivotal question in farm management research.

The current study builds on the dataset of Kramer *et al.* (2019b). This dataset consists of Farm Accountancy Data Network (FADN) data matched to government data on projects with interest-free investment credits. In this way, investments related to dairy barns can be identified. We extended the dataset by adding data from the Swiss agricultural census "Agrarpolitisches Informationssystem" (AGIS) (BLW, 2020). Although direct matching was not possible due to data privacy, spatial indicators could be derived from the AGIS data and combined with the existing dataset. The newly constructed dataset then helped us gain new insights into the mechanisms that link successful investments in dairy barns to the availability of land.

2. Materials and methods

Dataset

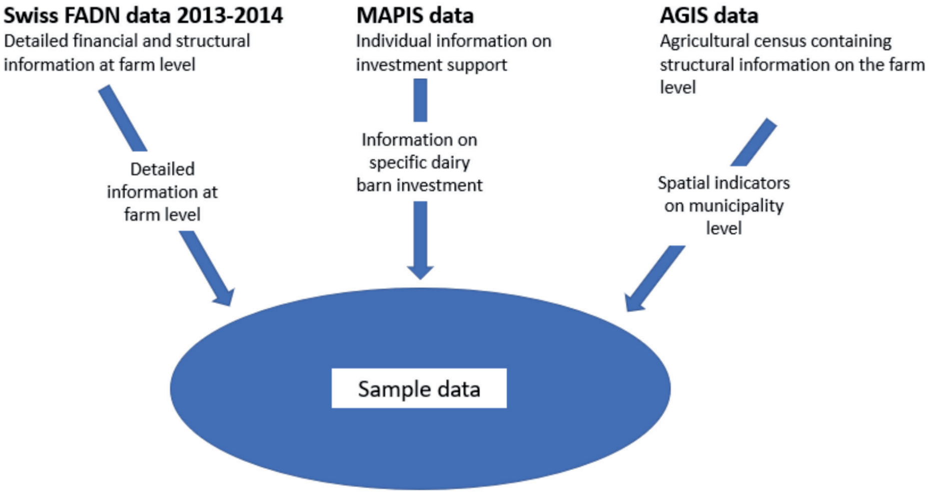
According to government officials from cantonal lending institutions, almost all major projects on dairy barns are supported by interest-free investment credits (Personal Communication, 2017). All projects subsidized by those credits are registered in a central database, the "Meliorations-und Agrarkredit-Projekt-Informationssystem" (MAPIS). Hence, by relying on this dataset, we captured all major dairy barn investments in Switzerland.

The Swiss FADN database comprises an unbalanced panel of farm data over time, with detailed data of the single farms. Details include information on key financial figures, farm structure, input of resources, inventories, yields and off-farm income. For the current study, we restricted the dataset to farms classified as specialized dairy farms (Type 21) or combined dairy-arable crop farms (Type 51) according to the Swiss FADN system (Hoop & Schmid, 2015). We also restricted the analysis to farms in the valley and hill regions, because farms in the mountain regions face largely different natural conditions. The years 2003 through 2014 were chosen as the period of investigation. Within this period, the methodology of data collection in the Swiss FADN system did not change.

By matching the described set of data with the MAPIS data, we derived a dataset with binding information of whether a farm had invested in a dairy barn. The resulting dataset was then restricted to farms, that had definitely invested in dairy barns. This dataset was used previously by Kramer *et al.* (2019b).

The complete agricultural structure in Switzerland is assessed by AGIS. The corresponding dataset contains structural data such as acreage, livestock, municipality and other details for all Swiss farms, but it does not contain financial data. A direct matching between the datasets of Kramer *et al.* (2019b) and AGIS was not possible for data protection reasons. However, it was possible to derive spatial indicators on the level of municipalities from the AGIS dataset and match them to the farms whose municipality was known from the first dataset. For example, the AGIS dataset allowed calculating the Gini coefficient within a municipality as a measure of concentration of all available acreage (calculation of the Gini coefficient is described in more detail in the subsection Independent Variables). In addition, the number of all subsidized dairy barn projects within a specific municipality over the chosen period could be determined. Other studies on spatial distribution used a much coarser resolution on the level of canton or higher (Huettel & Margarian, 2009; Mack, 2012; Sauer & Zilberman, 2012). The combination of the dataset is visualized in Figure 1 in order to facilitate the understanding of the dataset used.

Figure A.1 - Combination of the different datasets with their specific information that added up to the unique dataset used



Model and Dependent Variables

Kramer *et al.* (2019b) used two fixed-effects panel data models to analyze the effect of the investment on profitability and herd size, the latter measured by the annual difference in the number of dairy cow livestock units. There, the focus was on the adjustment of single farms after the investment. Therefore, intertemporal differences were of main interest leading to the choice of a fixed-effects model.

For the current study, building on the method of Kramer *et al.* (2019b), the focus was different – more on the relation between the farm's location and its investment than on the farm's evolution over time. Another difference was that we used agricultural income per family working unit (AI/FWU) as a measure of profitability. This measure can be viewed as the financial efficiency of the utilized family working units. The term Family Working Unit is defined in the Swiss FADN data as at least 280 working days per year (Hoop and Schmid, 2015). In the guidelines for data collection of FADN data (Jan & Schmid, 2015), a complete working day has a duration of at least 10 hours.

If a family working unit works more than 280 days per year for more than 10 hours a day, the additional amount of working time is not considered. This definition was developed for the Swiss FADN system since farmers usually do not keep track of their family labor input. Therefore, a full family working unit accounts for at least 2,800 hours per year. In the following, we first discuss the decision of the model and then explain the dependent variables.

Except off-farm income, for all our explanatory variables and the AI/FWU, the cross-sectional variance component was greater than the temporal component (Table A.1), which indicates that a random-effects model is preferred. The cross-sectional variance component of the annual difference in herd size and off-farm income was about the same order of magnitude as the temporal component. This higher contribution of the temporal component was partly due to the abandonment of the milk quota system[1].

The random-effects model is a frequently used approach in the literature. If a random-effects model is applicable, it has the advantage of allowing the straightforward inclusion of time-invariant explanatory variables. Moreover, the resulting model will be more efficient than its fixed-effects counterpart: If both a random-effects and a fixed-effects model are applicable, the random-effects model is more efficient, resulting in a narrower confidence interval for its computed coefficients. We tested the applicability of a random-effects model in three ways: using a straightforward Hausman test (Baltagi *et al.*,

1. With the abandonment of the milk quota system, dairy farms enlarged their dairy herd, which led partly to higher temporal variation for a short period.

2003), a Mundlak-type correlated random-effects model (Mundlak, 1978) and a fixed-effects vector decomposition model (Greene, 2011).

The models employed were also chosen to address endogeneity: The Mundlak model tested for evidence of a correlation between a time-invariant unobservable variable and our regressors. Because the notion of an endogenous variable can be considered an explanatory variable correlated with the error term of a regression, we determined and indicated correlations between the error term of the random-effects model and explanatory variables in the Appendix.

Table A.1 gives an overview of the descriptive statistics of the sample. The variables and their definitions are discussed in detail later in this section.

Table A.1 - Overall, cross-sectional and temporal components of variance of the variables employed

Variable	**Unit**	**Number of observations**	**Average**	**Minimum**	**Maximum**	**Standard Deviation**		
						overall	**between (cross-sectional)**	**within (temporal)**
FWU	–	418	1.33	0.41	2.53	0.34	0.29	0.17
AI/FWU	CHF/FWU	418	55,428	–31,387	231,634	35,529	28,339	21,787
ΔLU dairy cows	LU	418	1.40	–11.12	18.92	3.41	2.34	2.99
UAA	ha	418	27.32	8.57	59.47	8.72	8.98	1.76
Number subsidized projects in municipality	–	418	47.95	6.00	159.0	31.46	34.56	0.00
Gini coefficient	–	418	0.38	0.19	0.65	0.11	0.11	0.00
Dummy: region	1 = valley, 0 = hill	418	0.50	0.00	1.00	0.50	0.50	0.00
Dummy: milk quota	1 for year > 2009, 0 otherwise	418	0.39	0.00	1.00	0.49	0.35	0.38
Dummy: farm type	1 = Type 21, 0 = Type 51	418	0.75	0.00	1.00	0.44	0.45	0.04
Equity	Mio CHF	418	0.72	–0.11	2.97	0.48	0.48	0.11
Off-farm income	k CHF	418	45.68	0.00	1,250	92.56	58.22	69.92

CHF denotes Swiss francs. In 2017, the average exchange rate of the currency towards Euro was 1 CHF = 0.90 Euro, as retrieved from https://data.snb.ch on 12 March 2021. AI = agricultural income; FWU = family working unit; LU = livestock unit; UAA = utilized agricultural area.

In addition to the components given in Table A.1, we want to highlight a few peculiarities in the data. 53 % of the observations in the dataset had an off-farm income. Missing values were set to zero for analysis. It should be mentioned that the amount of full-time equivalent, that was put towards off-farm income was rather low for most observations (only one third of the observations with off-farm income dedicated more than 0.2 working units towards the off-farm income).

As mentioned before, we used AI/FWU besides herd size change as a dependent variable. Agricultural income is the farm income after interest on borrowed capital, taxes and paid labor. The AI/FWU is routinely calculated in the FADN data according to the following formula:

$$(1) \qquad AI/FWU = \frac{Agricultural\ Income - Calculated\ Interest\ on\ Owner's\ Equity}{Number\ of\ Family\ Working\ Units}$$

To calculate AI/FWU, calculated interest on owner's equity is subtracted from agricultural income. Interest on owner's equity is based on Swiss government bonds (Hoop & Schmid, 2015). Then, this residual number is divided by the number of family working units that are not already paid on a regular basis (Meier, 2000).

Besides AI/FWU, we analyzed herd size change. Following Kramer *et al.* (2019b), we used the change from one year to another to avoid distortions of the results from autocorrelation. Herd size was measured in terms of livestock units (LU). The change was calculated according to the following formula:

$$(2) \qquad \Delta LU\ dairy\ cows_{\ i,t} = N_{i,t} - N_{i,t-1}$$

For each dependent variable, a separate random-effects model relying on the same set of explanatory variables was used. The respective variables are described in the next subsection. The model is given by the following formula:

$$(3) \qquad \begin{aligned} X_{i,t} &= \alpha + ha\ UAA_{(i,t)}\beta_{ha} + No\ Pro_{(i,t)}\beta_{NoPro} + Gini_{(i)}\beta_{Gini} + Reg_{(i)}\beta_{Reg} \\ &+ Quota_{(i,t)}\beta_{Quota} + Type_{(i)}\beta_{Type} + Equ_{(i,t)}\beta_{Equ} + Non\ AI_{(i,t)}\beta_{Non\ AI} + \varepsilon_{(i,t)} + \mu_i \end{aligned}$$

X denotes the dependent variable, i.e., AI/FWU or change in herd size. α is the constant, ε denotes the individual specific error term and μ the remaining disturbance. The descriptive statistics of all used variables are stated in Table A.1, and their choice for the model is discussed in more detail in the next subsection.

Independent Variables

As pointed out in the previous sections, animal husbandry is closely linked to acreage. Due to this linkage, utilized agricultural area (UAA) was used as an independent variable with the abbreviation $ha\ UAA_{(i,t)}$.

The number of subsidized projects per municipality ($NoPro_{(i)}$) was used as a spatial variable. Spill-over and neighborhood effects related to the number of investing farms have previously been discussed in the literature (Mack, 2012; Sauer & Zilberman, 2012; Hüttel & Margarian, 2009) in the context of whether the level of surrounding investments rather trigger or inhibit the investment of a neighboring farm,. According to them, a higher number of investing farms – in our case measurable by the number of subsidized projects per municipality – could encourage a farm to invest if neighboring farms do so, through knowledge spill-over or visual example. However, also the opposite could occur and a farm planning to invest could be discouraged by a high level of investments of neighboring farms. because increased competition for resources could be expected. It must be noted that comparisons with findings in the above-mentioned literature would not be straightforward, larger regions were analyzed, not municipalities.

Another variable linked to spatial distribution was the Gini coefficient ($Gini_{(i)}$). The Gini coefficient is a measure to describe the degree of concentration (or inequality) of a distribution. In the literature, it has mainly been used to analyze the concentration of income or wealth. A Gini coefficient of 0 denotes total equality of the distribution, e.g., everyone of a large population being equally wealthy if analyzing the concentration of distribution of wealth. A Gini coefficient of 1 corresponds to total inequality, e.g., one person of the population holding the entire wealth of the population of which the wealth distribution is studied. Central to the calculation of the Gini coefficient is the distribution of a good of finite quantity, e.g., wealth or agricultural land, within a population of n individuals. For the calculation of the Gini coefficient, the following formula was used, where the individuals possessing the good or land are ordered by increasing amount of the good or land:

(4) $$G = \frac{n}{n-1} * \left(\frac{2\sum_{i=1}^{n} i x_{(i)}}{n\sum_{i=1}^{n} x_{(i)}} - \frac{n+1}{n}\right),$$

where $x_{(i)}$ denotes an element in the sorted data, in our case of agricultural land in the municipality. For two reasons, the Gini coefficient was used as a time-invariant variable. Firstly, this measure changes only slightly over time. For example, Huettel and Margarian (2009) observed an increase in the Gini coefficient in the fast-changing West-German agriculture from 0.44

in 1979 to 0.54 in 1999. Secondly and more importantly in our study, some municipalities have undergone administrative reforms, e.g., merged, and only the municipality structure at the end of the observation period was obtainable.

The Gini coefficient has been used frequently in the agricultural economics literature. Deininger and Squire (1998) and, following their work, Vollrath (2007) used the Gini coefficient to analyze the distribution of agricultural land among farms. Vollrath (2007) analyzed the relation of productivity and land distribution over different countries and found a negative influence of concentration on productivity. This negative influence was attributed to a lack of land market efficiency, which prevents the distribution from attaining an optimum point. Whereas Vollrath (2007) conducted a macroeconomic study, the Gini coefficient has also been used on a microeconomic level (Huettel & Margarian, 2009; Zimmermann & Heckelei, 2012). A more even distribution (i.e., a lower Gini coefficient) might represent a market, where medium-sized farms have the potential to take over agricultural land from other farms in order to grow. On the other hand, large farms in concentrated markets (displaying a higher Gini coefficient) might already have enough acreage to utilize additional capacity from investment more quickly.

The independent variables $Reg_{(i)}$, $Quota_{(i,t)}$ and $Type_{(i)}$ were, in line with Kramer *et al.* (2019b), also part of our model. They controlled for region, (milk) quota abolishment and farm type, respectively. The sample was restricted to the valley and hill regions according to the Swiss FADN system and distinguished by the region dummy. Because quota abolishment occurred within the observed time span, a quota dummy was used to indicate years when the quota system was in place and years after abolishment from 2009 onwards. Another difference between the farms, arising from the Swiss FADN system, was farm type. We used specialized dairy farms and combined dairy-arable crop farms distinguished by means of a farm-type dummy variable.

Equity ($Equ_{(i,t)}$) plays a crucial role for investments. It allows the access to borrowed capital, restricting the size of credits. Particularly agricultural land serves as security for borrowed capital, thus facilitating credit access (Vollrath, 2007). There is also a direct link between equity and credit rationing for Swiss farms, because the total amount of mortgaging on agricultural land is restricted by law (Bundesrat, 1991). In addition, equity was shown to be a statistically significant variable for this dataset in other applications (Kramer *et al.*, 2019a).

Non-agricultural income or off-farm income ($Non\ AI_{(i,t)}$) is of frequent interest in agricultural economics literature – particularly concerning cause and effect of part-time farming. Mittenzwei and Mann (2017) showed that specialization in either an agricultural or a non-agricultural profession is financially more viable than a combination of both. Therefore, in their point of view, a combination is rather seen as a lifestyle choice. It remains ambiguous if or when non-agricultural income becomes necessary in case of low financial power of the farm. Hennessy and O' Brien (2008) analyzed Irish farms for a substitution effect of labor due to non-agricultural income and found a decrease in probability of investment if the farmer earned an off-farm income. Based on economic theory, one would expect investments in labor-saving technologies if labor is better utilized financially in off-farm employment (Hennessy and O' Brien, 2008). The Swiss FADN dataset contains the information if off-farm income is obtained from employment or self-employment. In addition, the dataset contains information how much fulltime equivalent has been dedicated to obtain that off-farm income. We used the sum from employment and self-employment, divided by fulltime equivalent. Therefore, this variable reflects the wage level in the off-farm labor market.

3. Results

Table A.2 presents the results of two random-effects models, one for the annual AI/FWU, the other for the annual difference in herd size based on livestock units (ΔLU dairy cows). By means of a Wald test, the overall significance of both random-effects models was assessed as being very high ($P < 0.001$).

By means of the Hausman test, the appropriateness of the random-effects models was demonstrated with a P-value of 0.31 (AI/FWU) and 0.65 (ΔLU dairy cows). The appropriateness of the Mundlak-type correlated random-effects model was demonstrated by none of the time-averaged regressors being significantly different from zero (see Appendix: Table A.3). The Mundlak models indicated that endogeneity was not of strong importance for our chosen set of variables for the random-effects model. We further addressed this issue by indicating correlations between the error term of the random-effects model and the explanatory variables in the Appendix (Table A.4). The fixed-effects vector decomposition model was consistent with the random-effects model, with the random-effects being more efficient (P-values of corresponding Hausman tests: 0.85 for AI/FWU and 0.96 for ΔLU dairy cows).

Both models showed a higher coefficient of determination between individuals than within.

For the model of AI/FWU, all independent variables, except the Gini coefficient and farm type, were significant below the 10% level of the P-value. The more agricultural area a farm utilized, the higher was the AI/FWU. Also, the number of subsidized projects within a municipality resulted as significant, albeit with a smaller effect as apparent from the coefficient and the standard deviation.

Table A.2 - Results of the random-effects model for agricultural income per family working unit (AI/FWU) and herd size change

Model result	AI/FWU			ΔLU dairy cows		
R^2 within	0.0847			0.0324		
R^2 between	0.2957			0.3349		
R^2 overall	0.2056			0.0875		
Variable	**Coefficient**	**Standard error**	**P-value**	**Coefficient**	**Standard error**	**P-value**
UAA	1,498.2	326.8	0.00	0.07	0.03	0.01
Subsidized projects per municipality	160.0	88.7	0.07	−0.01	0.01	0.09
Gini coefficient	−19,235.4	27,734.5	0.49	−3.81	2.00	0.06
Dummy: region	1,488.2	6,693.8	0.09	0.09	0.48	0.86
Dummy: milk quota	−6,688.6	2,934.7	0.02	1.15	0.36	0.00
Dummy: farm type	1,171.2	7,401.5	0.87	−0.64	0.55	0.24
Equity	12,785.8	5,800.0	0.03	0.63	0.46	0.17
Off-farm income	17.5	15.5	0.26	0.00	0.00	0.96
Constant	1,074.9	15,691.6	0.96	0.97	1.13	0.39

ΔLU = difference in livestock units; UAA = utilized agricultural area. Cells shaded in green indicate statistically significant effects below the 10% level of the P-value.

Farms in the valley regions showed a significantly higher AI/FWU than farms in the hill regions. Milk quota abolishment had a negative effect on AI/FWU, as shown by the negative coefficient for the respective dummy. In investment literature, equity is commonly used as a key variable. In the present study, the effect was significant and in the middle range by size: An increase in equity by one standard deviation (approximately 0.5 million CHF) corresponded to a change in AI/FWU of 6,100 CHF.

For herd size change, mainly structural variables were statistically significant: acreage, subsidized projects per municipality, the Gini coefficient and milk quota dummy. Acreage had a positive and significant effect on herd size change. The number of subsidized projects within a municipality was also statistically significant for change in herd size, having a negative effect on this variable: The more projects within a municipality were subsidized, the less a dairy herd grew. Also, a higher Gini coefficient was concomitant with a smaller herd size change: The more concentrated the agricultural land was distributed within a municipality, the less growth in herd size could be expected. While quota abolishment led to lower levels of AI/FWU in investing farms, it allowed them to expand their herds, as indicated by the higher coefficient for herd size change after the year 2009.

4. Discussion

The selection of the appropriate model has been discussed and shown in the previous sections. It should be noted that herd size change was computed from herd size in the dataset and exhibits a larger variation than herd size in absolute values.

For growth in herd size, we found the number of subsidized projects in a farm's municipality to be a valid indicator of neighborhood effects: More subsidized projects resulted in less growth. According to government officials (Personal Communication, 2017), almost no investment in a dairy farm building is made without subsidies. Hence, the number of subsidized projects within a municipality might be highly correlated to the total number of dairy farm buildings in the municipality. This assumed relationship supports the hypothesis that with increased density of investments in one area, the competition for land increases as well, leading to smaller increases in herd size or different investments like labor-saving technologies.

In contrast to growth in herd size, the AI/FWU was positively influenced by the number of subsidized projects. Although the neighborhood (competition) can have a negative effect on the availability of land and consequently on additional livestock units, neighborhood seems to have a positive impact on management, leading to higher income. Although the effect in our study not highly significant, it was similar to the neighborhood effects found for the conversion to organic farming (Schmidtner *et al.*, 2012) and suckler cow husbandry (Mack, 2012) or the introduction of milking robots (Sauer & Zilberman, 2012). In addition, it is important to mention that the issue of cooperation was not addressed in this study.

The positive impact of subsidized projects in a municipality on AI/FWU is an important implication for agricultural policy makers since Swiss agricultural policy aims at a setting that allows farms to generate an income comparable to other sectors (Bundesrat, 1998c). Almost all farms investing in dairy barns which apply for interest-free loans are granted investment aids. This makes sense in the light of the number of subsidized projects having a positive impact on AI/FWU.

The negative impact of the Gini coefficient on herd size change is in line with previous findings in the relevant literature. A smaller mobility of resources has been documented when larger inequalities existed between farms (Huettel & Margarian, 2009; Zimmermann & Heckelei, 2012). The larger the Gini coefficient was in our analysis, the smaller was the herd size change and vice versa. This inverse relationship can be interpreted as follows: Investing farms in areas where acreage is distributed more evenly, manage to acquire (relatively) more land, allowing for a larger increase in herd size.

In order to gain insight for the interpretation of the results for Gini-coefficients, we compared means of the sample below and above the median of the Gini-coefficient. Below the median, off-farm income and acreage is lower, while herd size change, number of subsidized projects in a municipality and equity are higher. In addition, more farms are located in the valley region and the share of pure dairy farms is higher (data not presented). This might point to less possibility to switch to a job outside farming, itself leading to fewer labor-saving investments, more investments into a strictly lager barn. A positive influence of larger acreage on herd size expansion has previously been shown (Kramer *et al.*, 2019b). To increase herd size or profitability, the presence of sufficient acreage in a farm is crucial. This key characteristic was clearly supported by our regression results, with the effect of acreage being highly significant (and having the highest impact for an increase by one standard deviation for both models). The effect was larger for AI/FWU than for herd size change. However, the magnitude of direct payments is strongly linked to acreage. At first glance, the coefficient of acreage for herd size change can be considered small. Bewley *et al.* (2001) analyzed experiences of US dairy farmers who had recently expanded their dairy herd in the aftermath of investments. They observed that herd size grew faster than acreage. However, the high level of direct payments in Switzerland, which requires the farmers to keep their livestock density below a certain level (Bundesrat, 1998a), might contribute to this coefficient, being not as large as in other countries. Although, the coefficient was highly significant and large, compared to the other variables in the result.

The effect of milk quota abolishment present in our study is in line with basic economic theory. With quota abolishment, Swiss farms increased their milk production considerably and maintained this level (Finger *et al.*, 2013). For the investing farms in this sample, our analysis showed that this increase in productivity was achieved by an increase in herd size on an individual basis for each farm. Supply restrictions such as milk quota are considered to lead to higher production costs and inefficient structures (Richards & Jeffrey, 1997). This might not necessarily translate into higher margins for the producers – for example, Huettel und Jongeneel (2011) could not find unambiguous effects for rents of quota owners. Alongside an increase in herd size, AI/FWU dropped in our study when quotas were abolished. Finger *et al.* (2013) pointed out that given the price drop after quota abolishment, sector production remained on the newly achieved high level.

A positive influence of equity was expected due to equity restricting the amount of borrowed capital by law (Bundesrat, 1991). As can be seen from the results, the effect for Swiss dairy farms was in the middle range, when magnitude of coefficient and standard deviation are taken into account. The effect might be limited for different reasons. First and foremost, the governmental institutions responsible for distributing subsidies and official investment credits among farms are allowed to expand the total amount of credit in this special case of investment (Bundesrat, 1991). Hence, this linkage and the contribution of equity might be more prominent in other investments where farmers have to rely on capital from private investors. In addition to the special case of dairy barns, the small effect of equity might stem from the low level of interest rates. For example, interest rates for 10-year Swiss government bonds kept decreasing from 2.4% in 2003 to negative values in 2015 (SNB, 2021). This development means that opportunity cost for equity diminished over time.

No evidence can be drawn from the data on the different hypotheses about off-farm income. It could be possible, that the high share in observations of small amounts of work put to off-farm income added a considerable amount of variation, thus preventing the coefficient from achieving a statistically significant level. On the other hand, only considering higher levels of working units put to off-farm work would be arbitrary.

5. Conclusions

By combining three different sources of data, namely, FADN, MAPIS and AGIS data, we constructed a unique dataset apt to analyze influencing factors especially from a farm's neighborhood on two key variables of investing farms: herd size change and AI/FWU, with the latter allowing for comparison of financial productivity of unpaid family labor input. By means of two spatial indicators, the number of subsidized projects and the Gini coefficient measuring the equality of the distribution of agricultural land at municipality level, we analyzed the influence of neighboring farms on investing farms. We found that neighborhood had an impact on investing farms and that the impact was twofold. Firstly, growth in herd size was limited by a high number of subsidized projects and a high concentration of land (Gini coefficient). The competition for land, due to governmental regulation directly linked to herd size, was intense and an obstacle for growth. Secondly, neighborhood effects as measured by the number of subsidized projects positively influenced the farms' management, leading to a higher AI/FWU. In the case of intense competition for land, a high performance of a farm would be needed to offer an expected high rate for rental land. We conclude that an intense dairy farm neighborhood is a challenging precondition for an investment. In such cases, a cooperation with another dairy farm is an option to realize a substantial economies-of-scale effect. In addition, a switch to a production different from dairying with a more favorable neighborhood influence could be an option.

Although the conducted analysis has several links to agricultural policy (in particular subsidized projects), there is no compelling policy conclusion due to the twofold effects which were found. One could hypothesize that investments in locations with a high number of subsidized projects and an unequal distribution of land are of a different type, e.g., related to labor-saving consequences only with higher AI/FWU and less pronounced or lower change in herd size.

This hypothesis is underscored by looking at the sample of farms split along the median of the Gini coefficient into cases of low Gini coefficients (more equally distributed agricultural area) and high Gini coefficients (highly concentrated distribution of agricultural area). Lower farm in municipalities with a low Gini-coefficient might lead to fewer labor-saving technologies and more into a strictly larger barn. However, proving these assumptions about the distinction in types of investments would require further research. Based on this additional research, it might however be possible to derive implications for agricultural policy measures. A negative neighborhood effect would confront policy makers with the ethical dilemma of deciding who is supported and who not.

Looking at the results of the regressions, we can point out that mainly structural variables were of importance for herd size change. Concentration of land and more subsidized projects within a municipality inhibited herd size growth. Milk quota abolishment was an event affecting both key variables considerably.

Overall, our analysis took advantage and relied on the details of our data sources. By matching and adding indicators, the FADN dataset which aims to reflect a representative sample of all farms could be used to analyze rather specific research questions from only a small subsample that could not have been identified otherwise. This illustrates, that more detailed information about investments would further help to address specific research questions.

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Appendix

Table A.3 - P-values of the coefficients for time-averaged regressors of the Mundlak-models

Time-averaged regressor	In the model for AI/FWU, *P*-value	In the model for ΔLU dairy cows, *P*-value
UAA	0.11	0.25
Subsidized projects in municipality	NA	NA
Gini coefficient	NA	NA
Dummy: region (valley = 1, hill = 0)	NA	NA
Dummy: milk quota (abolished = 1, in effect = 0)	0.60	0.30
Dummy: farm type (Type 21 = 1, Type 51 = 0)	0.98	0.82
Equity	0.79	0.42
Off-farm income	0.98	0.91

The number of subsidized projects and the Gini-coefficient did not vary over time; hence, time-averaged regressors could not be constructed (NA = not applicable). AI/FWU = agricultural income per farm working unit; LU = livestock unit; UAA = utilized agricultural area.

Table A.4 - Correlations of independent variables and residues of the random-effects models

Variable	Correlation (P-values) with residues of random-effects model	
	for AI/FWU	for ΔLU dairy cows
UAA	−0.05 *(0.29)*	−0.02 *(0.74)*
Subsidized projects in municipality	−0.00 *(0.95)*	0.01 *(0.85)*
Gini coefficient	0.04 *(0.38)*	−0.01 *(0.86)*
Dummy: region (valley = 1, hill = 0)	−0.02 *(0.62)*	0.00 *(0.93)*
Dummy: milk quota (abolished = 1, in effect = 0)	0.00 *(0.95)*	−0.01 *(0.80)*
Dummy: farm type (Type 21 = 1, Type 51 = 0)	−0.03 *(0.58)*	−0.00 *(0.95)*
Equity	0.01 *(0.86)*	−0.01 *(0.83)*
Off-farm income	−0.03 *(0.60)*	0.00 *(1.00)*

AI/FWU = agricultural income per farm working unit; LU = livestock unit; UAA = utilized agricultural area.

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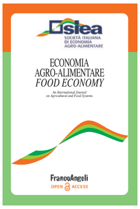
Economia agro-alimentare /
Food Economy

An International Journal on Agricultural and Food Systems

Vol. 23, Iss. 3, Art. 17, pp. 1-20 - ISSN 1126-1668 - ISSNe 1972-4802
DOI: 10.3280/ecag2021oa12779



The impact of irrigation on agricultural productivity: the case of FADN farms in Veneto

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Abstract

The aim of the research is to analyze economic aspects related to the use of water in agriculture, by evaluating the effect of irrigation on agricultural productivity in a sample of FADN farms in the Veneto region in 2018. Specifically, the change of the Gross Saleable Production (GSP) is analysed as against the binary variable use/non-use of irrigation by applying an econometric analysis. To estimate how irrigation might influence GSP we have considered, in addition to the variable use/non-use of irrigation, other explanatory variables that could leverage the GSP, in particular 'variable costs', 'use of land' and 'UAA'. Results of the analysis show that a positive relationship exists between irrigation and the GSP. This result is considered relevant in the context of water resource management policies.

Article info

Type:
Article
Submitted:
15/05/2021
Accepted:
10/10/2021
Available online:
12/01/2022

JEL codes:
Q15, Q25, C01

Keywords:
Irrigation
Land productivity
Water value

Managing Editor:
Lucia Briamonte,
Luca Cesaro,
Alfonso Scardera

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Introduction

The use of irrigation in agriculture is key for the providing the World food supply (FAO, 2003). Irrigation contributes to stabilise crops productivity by providing a controlled quantity of water when rainfalls are not sufficient, or they could not guarantee the adequate agricultural productivity (Rossi, 2019). Agricultural production is strongly dependent from water availability and, therefore, is also exposed to risks related to the lack of it, such as the case of drought. The agricultural sector alone accounts for 40% of the total annual withdrawal of water in Europe (European Environment Agency, 2019). Economic and environmental aspects linked to water use play a key role in relation to policies for water management, such as the Directive 2000/60/EC (Water Framework Directive). The assessment of socio-economic relevance of water uses provides helpful information to recognise the value of water as an input to be used in production processes (Working Group 2.6 - WATECO, 2003).

The literature on this topic includes few studies about the assessment of the economic impact of irrigation.

Kirsten and J. Van Zyl (1990) use the input-output analysis to evaluate the economic impact of the development of irrigation in the South-West of the Orange Free State (today Free State province of the Republic of South Africa). The authors, through the Leontief inverse matrix, show that irrigation produces not only direct impacts on the agricultural sector but also indirect ones on other sectors and consumption.

Babovic *et al.* (2009) compare the economic efficiency of irrigated and dry agricultural production of a farm in the Bačko Gradište village, in the autonomous province of Vojvodina in Serbia. The authors use a comparative analysis of data collected and they analyse the farm's economic performance before and after the introduction of irrigation. Results show the positive effects that irrigation have on production yield and farm profitability.

Columba and Altamore (2006) compare the GSP and the Gross Profit Margin of agricultural holdings of Italian southern regions. They prove that irrigation can enhance production and economic performance of crops, both of those that need irrigation and those that not necessarily need it, but they perform better with the use of water. Authors estimate that half of the national economic value of agricultural production derives from irrigated crops, which account for 1/5 of the Utilised Agricultural Area (UAA).

Rosato and Rotaris (2014), in the framework of the "Rapporto condizionalità ex-ante per le risorse idriche: opportunità e vincoli per il mondo agricolo" (edited by Zucaro, 2014), evaluate the effect of irrigation in Italy starting from the agricultural farmland values and applying an econometric approach. This analysis enabled to estimate a statistically significant relation between the agricultural farmland values and the possibility to irrigate. Results show that irrigation contributes significantly to increase agricultural farmland values, particularly where irrigation and specialised crops are more widespread. Data used to perform the analysis were taken from different sources, such as SIGRIAN (National Information System for the Management of Water Resources in Agriculture), ISTAT Agricultural Census, Revenue Agency, National Agrometeorology Database.

The economic importance of water in agriculture is also highlighted by studies that estimate the impact of drought on irrigated agriculture. Lopez *et al.* (2017) present an integrated framework to predict the direct economic impacts of drought on irrigated agriculture. They consider the uncertainty about water availability and crop price volatility, combining econometric assessment, stochastic projection of inflows and simulation system operation. The authors show that drought has an economic impact in terms of loss of production. Giannoccaro *et al.* (2019) conducted an empirical assessment of the impact that the reduction of water availability has on tomato production in the Capitanata area in the Apulia region. The authors estimate that the drought events that occurred in the period of interest caused losses of 30% compared to the years with regular water availability.

The present research aims to provide additional evidence about the economic impact of irrigation on agricultural productivity, by applying an econometric analysis to the data extracted by the Farm Accountancy Data Network (FADN) of farms for the Veneto region in 2018.

Veneto is among the first four more important Italian agricultural regions; it leads in several productions and can count on agricultural holdings rather diversified. In the last twenty years, agriculture in Veneto has faced various changes due to market trends, the innovations introduced by the reforms of EU policies and those generated by technological progress, as well as the increasingly pressing challenges caused by climate change and environmental problems. From the point of view of adaptation to climate change, one of the major potential risks is represented by the management of water resources, which is not always able to respond to the growing needs of the territory (42% of the regional UAA was irrigated in 2016). In Veneto there is a good availability of water, despite the uneven distribution of rainfall, but the state of the infrastructures still causes losses of this precious resource. Faced with a progressive increase in the demand for irrigation water, technological innovations are being introduced in the distribution systems to improve overall efficiency.

In the 2008-2018 decade agricultural and forestry holdings of the Region decreased of 22.5%, going from 82,582 units in 2008 to 64,182 in 2018. This reduction is in line with the national performance (–18.5%), even though it is slightly higher. This decreasing trend had been registered already since

1997. From 2008 less farms abandoned the sector compared to the previous decade, but despite this the balance between farms leaving the sectors and those entering was still negative. The reduced number of farms matches also the reduction of the UAA that, in the decade considered, decreased of 2.5%, reaching 778,000 ha in 2018. The decline of both number of farms and UAA has become a structural characteristic of the regional agriculture. It is important to note, however, that the UAA changes followed a fluctuating trend, not always negative and with a decline less evident than that registered for the number of holdings. Looking at single crops, cereals (–27,8%), horticulture (–21,1%), orchards (–17,5%), and forage crops (–16%) registered major reductions, while industrial crops increased the most. Important increases have been registered in viticulture (+17%), olive growing (+7,8%), legume vegetables and tuber crops (+4,7%). Despite the negative trend of the UAA and farms' number, the agricultural production value improved of 18.5%, overcoming three billion euros in 2018. This positive result is mainly due to the increased value of production in two sectors, that are industrial crops and viticulture. Between 2013 and 2018 the production of grapes for quality wines increased. The same happened for the cultivation of olive trees, whose economic values is more than duplicated in the same period, even though in absolute terms the growth can be considered marginal (Veneto Agricoltura, 2020).

For what rainfalls are concerned, Veneto has experienced a progressive deterioration of the water balance from the 1980s, with a negative peak in 2003. As a consequence, the water-climate balance in the Veneto region went from positive to negative values (Zucaro e Povellato, 2009). Unfavourable climate trends, such as temperature increase and the changes of rainfalls seasonality, boosted the use of irrigation on agricultural areas, which are limited in terms of extension, but important from an economic point of view, as it is the case of vineyards. Hence, sustainable water management became a priority for the Region. On the light of this, the allocation of financial resources dedicated to agriculture, such as those provided by the rural development policy, is strongly oriented to preserve natural resources, including water. The Veneto region has included in the 2014-2020 Rural Development Programme (RDP), funded by the European Agricultural Fund for Rural Development, a set of measures with the aim to strengthen competitiveness of agricultural holdings in the global market, while addressing environmental objectives, as set up by European, national and regional policies. These measures support: the adoption of innovative solutions, including the introduction of technologies, sustainable also from an ecological perspective; the use of non-productive investments to achieve agro-environmental and climate objectives; investments for the modernisation of those infrastructures needed to ensure the development of agriculture and forestry. Several of the planned measures have positive effects on improving water management and the related infrastructures. It is important to notice that the Veneto RDP assigned almost 9 MEURO to Focus Area 5a "Increasing efficiency in water use by agriculture". Among the interventions that could deploy more positive effects on water use there is sub-measure 4.3 "Investments on forestry and agri-pastoral infrastructures, land consolidation and network services", which allowed the four regional irrigation consortia accessing financial resources to improve water efficiency in agriculture. The implementation of innovation-related measures has also effect on improving water use and management. At least 8 out of 56 Operational Groups (OG) funded in the region target directly improvement of water management, use and quality. Other OGs aiming at reintroducing old plant varieties, improving pest management and reducing the use of chemical inputs are also considered to have positive impact on water, particularly water quality and use. Interventions funded under M1 "Training" and M2 "Advisory services" contribute indirectly to the improvement of water management, by supporting the dissemination of information and knowledge.

The analysis of issues relating to the sustainable and efficient management of water in agriculture should take into account the potential of irrigation to provide several ecosystem services (Zucaro, 2014; Rogers *et al.*, 1998) often provided as positive externalities, since they are not captured by market mechanism (Natali & Branca, 2020). Some of these, such as aquifer recharge, are provided through the excess of water applied to the field and delivery losses (Dages *et al.*, 2009; Grafton *et al.*, 2020) which cause low efficiency. From this point of view, Veneto Region has territorial peculiarities that can generate ambiguous environmental impacts of water efficiency improve. This area is characterized by the spread of groundwater-surface water interactions, which, under specific conditions, might trigger a positive effect of irrigation to the aquifer recharge. The use of traditional irrigation practices, such as furrow and flood irrigation, causes the distribution of excessive quantities of water in the field. This water percolates in the subsoil, replenishes the aquifer and re-emerges on the surface, creating the resurgences phenomena (Fabbri *et al.*, 2016). It is important to note that the aquifer recharge processes through irrigation make it necessary to pay particular attention to the use of chemical inputs that might compromise the status of groundwater. In this paper, the economic aspects of water use in agriculture are addressed in order to verify how much irrigation can affect farms' productivity and viability in a specific area and time frame.

In this work we demonstrate the economic relevance of irrigation, while acknowledging that the comprehensiveness of the analysis would increase by considering additional aspects. For example, technical efficiency, including water use efficiency can influence farm's economic performance (Wichelns *et al.*, 2002; López-Mata *et al.*, 2019). This is not included in the quantitative analysis of this work; however, the results return acceptable estimates and allow for final considerations on the importance to further improve the efficiency of water use, especially through the intervention funded by the CAP (Common Agricultural Policy). The analysis of the economic implications of irrigation might be the basis for future developments of these results, including the analysis of the environmental dimension of the sustainable use of water.

1. Materials and methods

The analysis carried out focuses on the Veneto region. The sample used was extracted from the Farm Accountancy Data Network (FADN) database and refers to 2018. The absence of particular climatic anomalies that could influence the results was verified prior the selection of the time frame for the research. 2018 was not characterized by drought problems; the values recorded by the 12-month and seasonal Standard Precipitation Index (SPI) for 2018 in this region are within the norm (ISPRA, 2019). Furthermore, 2018 data is also the most recent one available in the FADN database.

To estimate the impact of irrigation on the farms' economic performance, we considered the variable GSP per hectare. The GSP includes the revenues strictly connected with the agricultural activity; therefore, the GSP per hectare represents land productivity and provides a preliminary indication of farms profitability. In the FADN database the utilised agricultural area (UAA) does not include the land dedicated to wood arboriculture. However, in order to consider the effects of this cultivation on the GSP, we added it to the UAA.

The dependent variable is represented by the ratio GSP/UAA, while the independent variable is the dummy use/not use of irrigation (IRRIGATION DUMMY in the Table 1), but we also analyse the percentage of irrigated UAA (IRR_UAA/UAA in the Table 1). We included additional control variables with the aim to consider other elements that could have influence on the GSP (Table 1). The UAA has been included to take in consideration potential effects of farm size on efficiency and viability (Hansson, 2008; Reidsma *et al.*, 2007). Variable costs (VC) include specific expenditure (water, crops insurance, chemical inputs, external contracts, seed, poles, etc.), other costs (energy, marketing and communication) and farm use[1]. Variable costs can be used to measure the level of input intensity undertaken by agricultural holdings (Reidsma *et al.*, 2007), which can affect crop yield (Reidsma *et al.*, 2007). Therefore, ratio between VC and UAA has been included in the analysis (VC/UAA).

1. Water costs are included in the variable vc.

Table 1 - Variables included in the analysis

Variabile	Meaning
UAA	Utilised agricultural area (included wood arboriculture) (thousand Ha)
AL/UAA	% of arable land compared to the total farm Utilised agricultural area (included wood arboriculture)
ARB/UAA	% of area for tree crops compared to the total farm utilised agricultural area (included wood arboriculture)
Meadow/UAA	% of grassland compared to the total farm utilised agricultural area (included wood arboriculture)
Wood/UAA	% of area for wood arboriculture compared to the total farm utilised agricultural area
VC/UAA	Ratio between Variable Costs and utilised agricultural area (included wood arboriculture) (expressed in thousands of € for each thousand Ha)
IRR_UAA/ UAA	% of irrigated UUA compared to the global UAA (included wood arboriculture)
Irrigation	Dummy variable presence/absence of irrigation
GSP/UAA	Ratio between Gross Sellable Production and Utilised agricultural area (included wood arboriculture) (expressed in thousands € for each thousand Ha)
UAA/AA	Ratio between Utilised agricultural area (included wood arboriculture) and total agricultural area (percentage)

Source: our elaboration on FADN data.

Different types of farming can influence economic results (Coppola *et al.*, 2018), therefore the percentage of different types of farming within the UAA have been considering as control variables, namely: i) share of UAA under tree crops (ARB/UAA); ii) share of UAA under arable land (AL/ UAA), ii) share of UAA for wood arboriculture (WOOD/UAA), iii) share of UAA/AA was included to control the percentage of land used specifically for agriculture. In fact, authors expect that farms with a higher percentage of UAA could have a better economic performance than those with higher percentages of land not used for agriculture (in term of GSP/UAA).

A data cleaning procedure was applied to the original dataset, composed by 577 observations. The rational of this operation was justified by the need to remove outliers associated to the variables of interest for the analysis. The cleaned dataset counts 530 valid observations. 47 observations were removed because at least one of the following issues were identified: Total Agricultural Area (AA) was equal to zero; the UAA was bigger than the AA; presence of odd or unexpected values in relation to the ratio GSP/UAA identified through the use of the *boxplot anomaly detection* technique; total agricultural area lower than the sum of the single crops' areas; irrigated area higher than the total agricultural area. We applied the natural logarithm to the variables GSP/UAA and VC/UAA to standardise the values distribution, being it strongly skewed. We implemented a descriptive univariate analysis of the studied variables and we calculated mean and standard deviation of quantitative variables and frequencies of qualitative variables. The linear correlation between quantitative variables was estimated using the Pearson correlation coefficient and illustrated with a matrix scatterplot. We conducted an independent sample t-test to assess if a statistically significant difference, in terms of GSP/UAA, exists between irrigated and non-irrigated farms, accompanied by a bar-plot representing average values and 95% confidence levels. As final step, we constructed a hierarchical multiple linear regression model to assess whether and which factors have a statistically significant impact on the variable under study GSP/UAA. In particular, the dummy variable use/not-use of irrigation was introduced in the first step, while in the second step also the control variables were introduced to assess whether there was a change in the effect and significance of the irrigation variable. In all the analyses mentioned, an alpha significance level of 0.05 was used. IBM SPSS Statistics software version 25 was used for the statistical analysis of the data.

2. Results

Table 2 shows the characteristics of the 530 farms analysed in relation to the variables of interest. With regard to the dichotomous variable that describes the presence or absence of irrigation, it is noted that in 54.3% of cases (equal to 288 holdings), farms resort to irrigation while in the remaining 45.7% of cases (equal to 242 holdings) they choose dry cultivation.

We carried out a correlation analysis to verify if and which variables were significantly correlated with the dependent variable under study (LN(GSP/UAA)). Table 3 shows only the statistically significant correlations, while the corresponding scatter plot (Figure 1) allows a graphical evaluation of the correlation itself. The variables in question are quantitative, therefore, the bivariate correlation index used is the Pearson coefficient.

It is possible to observe how the variable LN(GSP/UAA) is significantly and positively correlated with the variables LN(VC/UAA) ($r = .558$) and ARB/UAA (%) ($r = .392$), while it appears to be negatively correlated with the variables UAA (kha) ($r = -.348$) and UAA/TA (%) ($r = -.101$), despite the latter correlation being very slight.

Table 2 - Descriptive statistics of the variables included in the analysis after data cleaning and preparation

Variable	N	Min	Max	Mean	Std. Dev.
UAA (thous. Ha)	530	,01	6,14	1,15	1,17
AA (thous. Ha)	530	,02	8,25	1,34	1,35
UAA/AA (%)	530	17,48	100,00	84,77	14,05
LN(GSP/UAA)	530	–1,23	4,87	1,72	1,08
LN(VC/UAA)	530	–1,15	4,40	1,14	1,05
IRR_UAA/UAA (%)	530	,00	100,00	33,60	38,84
AL/UAA (%)	530	,00	100,00	60,74	41,22
ARB/UAA (%)	530	,00	100,00	28,36	38,19
Meadow/UAA (%)	530	,00	100,00	10,33	26,22
Wood/UAA (%)	530	,00	58,27	,57	3,88

Source: our elaboration on FADN data.

Table 3 - Correlation Matrix of the variables included in the analysis

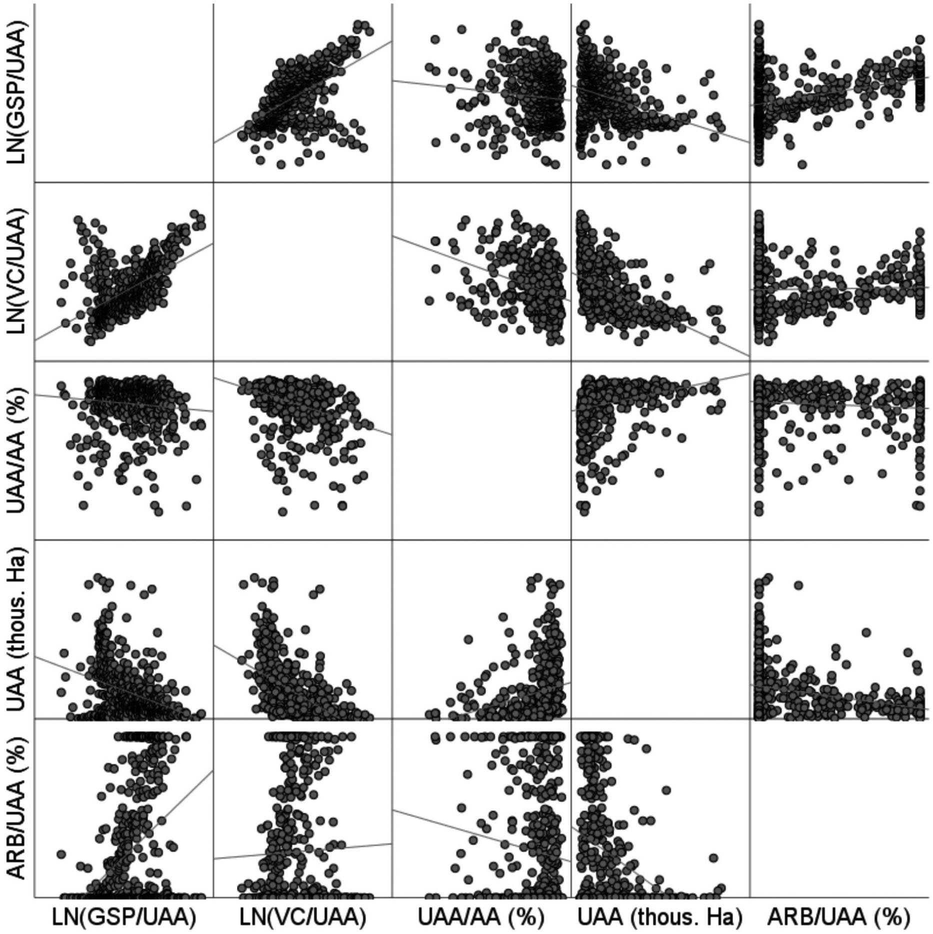
		LN (VC/UAA)	UAA/AA (%)	UAA (thous. Ha)	ARB/UAA (%)
LN(GSP/UAA)	Pearson correlation	,558***	-,101*	-,348***	,392***
	Sign. (two-tailed)	,000	,020	,000	,000
LN(VC/UAA)	Pearson correlation	1	-,342***	-,524***	,033
	Sign. (two-tailed)		,000	,000	,448
UAA/AA (%)	Pearson correlation		1	,250***	-,107*
	Sign. (two-tailed)			,000	,014
UAA (thous. ha)	Pearson correlation			1	-,316***
	Sign. (two-tailed)				,000
ARB/UAA (%)	Pearson correlation				1
	Sign. (two-tailed)				

* Correlation is significant at the 0.05 level (2-tailed significance test; H0: r=0).
** Correlation is significant at the 0.01 level (2-tailed significance test; H0: r=0).
*** Correlation is significant at the 0.001 level (2-tailed significance test; H0: r=0).

Source: our elaboration on FADN data.

An independent sample t-test was carried out to assess whether or not there was a difference in the mean value of LN(GSP/UAA) between farms with irrigation and farms without irrigation (Table 4). Given that the distribution

Figure 1 - Matrix scatter plot of the variables included in the analysis



of the variable LN(GSP/UAA) (Figure 2) can be considered acceptably normal and the adequate sample size, we judged that it was not necessary to use non-parametric tests.

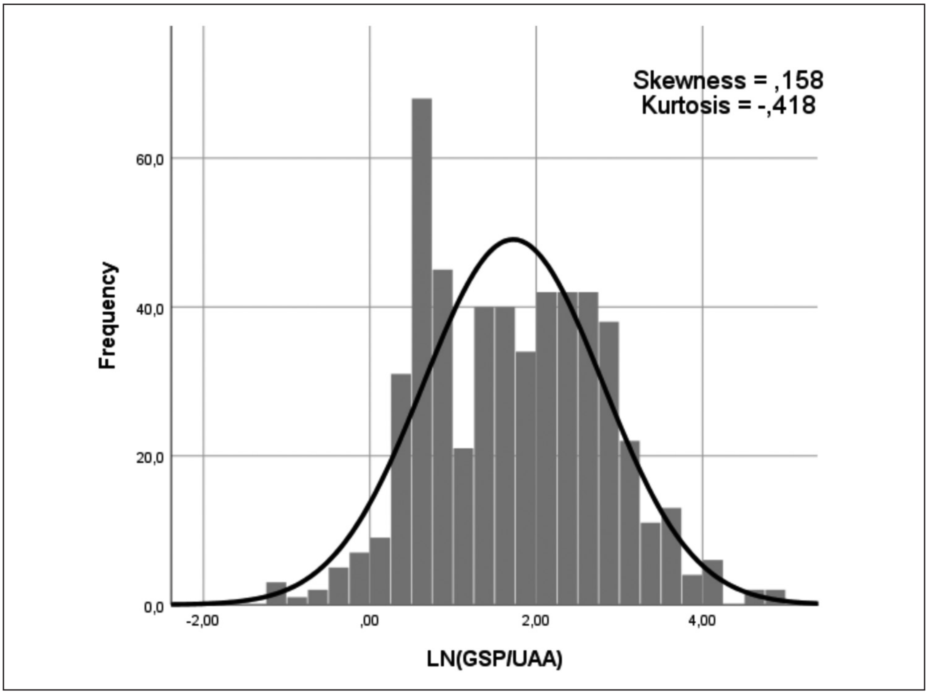
Since the Levene test for the equality of variances in the subgroups was not significant (p = 0.323), no robustness correction was made to the independent-sample t-test, which was found to be not statistically significant (t = -,405; df = 528; p = .686). It was therefore concluded that, in the absence of control variables, the difference in terms of natural logarithm of the GSP/UAA ratio between farms with and without irrigation is not significant. Figure 3 presents this difference through a bar graph with a mean and 95% confidence interval.

Table 4 - Descriptive statistics for the difference of the mean of LN(GSP/UAA) between farms with and without irrigation

	Irrigation	N	Mean	Std. Dev.	Std. Error
LN(GSP/UAA)	No	242	1,7028	1,12257	,07216
	Yes	288	1,7409	1,03919	,06123

Source: our elaboration on FADN data.

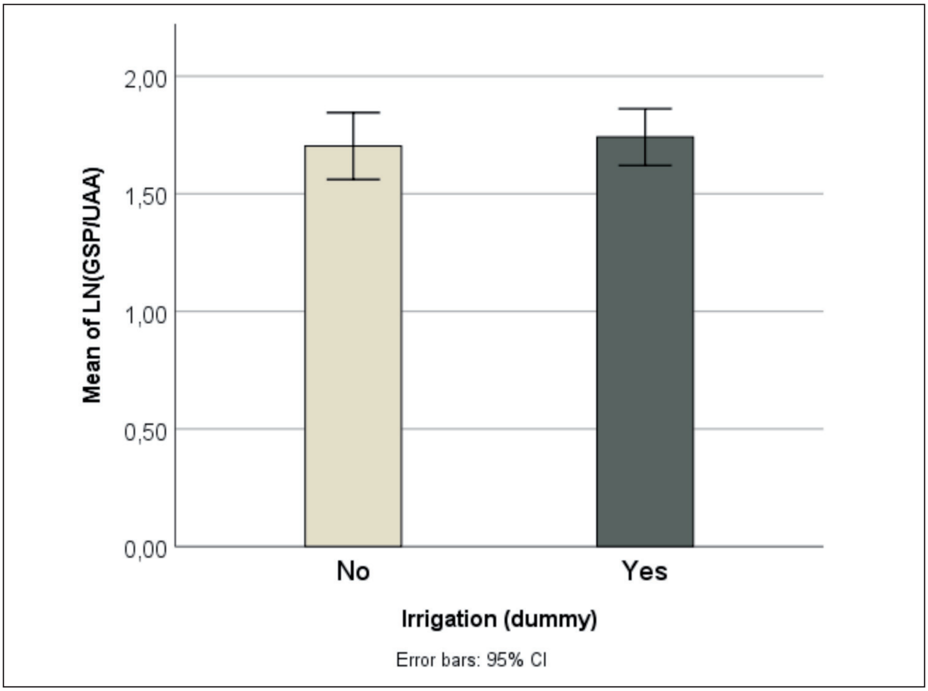
Figure 2 - Histogram of the distribution of the variable LN(GSP/UAA)



Source: our elaboration on FADN data.

The fact of not having observed, through the t-test, statistically significant differences in the presence or absence of irrigation with respect to the variable LN(GSP/UAA) could erroneously lead to think that this evidence is sufficient to exclude an effect of irrigation in terms of productivity of agricultural holdings. However, the two subgroups of farms with and without irrigation might have different dimensional, cultural and structural characteristics, thus making the direct comparison through t-test potentially biased.

Figure 3 - Bar graph of the mean of the LN(PLV/SAU) with and without irrigation



Source: our elaboration on FADN data.

In order to isolate the single effect of irrigation on productivity, we constructed a hierarchical multiple linear regression model, the results of which are shown in Table 5. In the first step, only the dichotomous independent variable "Irrigation" was included in the model, while the control variables LN(VC/UAA), UAA/TAA (%), UAA (kha) and ARB/UAA (%) were added to the second step in order to evaluate and quantify the impact of irrigation for given variable costs, used agricultural area, percentage of the used agricultural area compared to the total agricultural area and the type of crop. During the model selection procedure, all variables linked to the share of different types of farming [AL/UAA (%), ARB/UAA (%), Meadow/UAA (%) and Wood/UAA (%)] have been included. Nevertheless, only the variable ARB/UAA had a strong, significant, and positive effect on economic performance, while the others had non-significant effect. Therefore, only variable ARB/UAA was included, to keep the model specification as simple as possible, in accordance with the parsimony criterion, widely used in multiple linear regression models to avoid collinearity problems.

Table 5 - Hierarchical multiple linear regression models

Model		Unstandardized coefficients		Standardized coefficients	t	Sig.	Collinearity Statistics	
		B	Std. Error	Beta			Tolerance	VIF
1[a]	(Constant)	1,703	,069		24,572	,000		
	Irrigation (dummy)	,038	,094	,018	,405	,686	1,000	1,000
2[a]	(Constant)	-,297	,250		-1,189	,235		
	Irrigation (dummy)	,155*	,073	,072	2,129	,034	,883	1,133
	LN(VC/UAA)	,639***	,040	,623	15,880	,000	,648	1,544
	UAA/AA (%)	,009**	,003	,121	3,484	,001	,821	1,217
	UAA (thous. Ha)	,070	,037	,076	1,903	,058	,633	1,579
	ARB/UAA (%)	,012***	,001	,425	12,304	,000	,835	1,198

a. Dependent variable: LN(GSP/UAA).
* Statistically significant coefficient at 0,05 level.
** Statistically significant coefficient at 0,01 level.
*** Statistically significant coefficient at 0,001 level.

Source: our elaboration on FADN data.

At the first step, as evidenced by the non-significance of the t-test, the *Irrigation* variable has an estimated coefficient equal to .038 which is not statistically significant (p = .686); moreover, the model appears to be not significant ($F_{1,528}$ = ,164; p = ,686) and the variance explained by the model is close to zero ($R^2 < 0.001$).

In the second step, however, following the addition of the control variables, the estimated coefficient for the Irrigation variable rises to .155 and it is statistically significant at the 0.05 level (p = .034); furthermore, the model appears to be overall significant ($F_{5;524}$ = 95,624; p < .001); (and the variance explained is considerable ($R^2 = 0.477$).

We assume that for given variable costs per hectare of utilised agricultural area, percentage of UAA/TAA and type of crop, irrigation has a positive and statistically significant effect on the productivity of farms, measured as the GSP/UAA ratio.

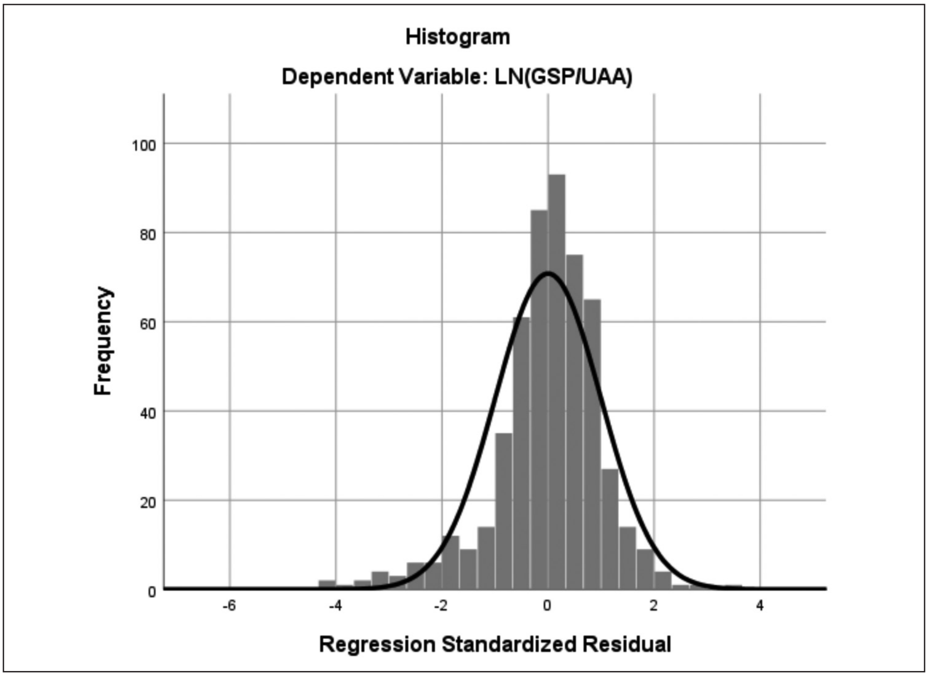
A regression with IRR_UAA/UAA as independent variable has been run but this model had a worse fit and the IRR_UAA/UAA variable had a non-statistically significant estimated coefficient. Therefore, the presence or absence of the irrigation is more predictive than the percentage of the irrigated area, in terms of economic performance of companies.

It is also interesting to observe that the effect for the control variables LN(VC/UAA), UAA/TAA (%) and ARB/UAA (%) is positive and statistically significant, while the effect of the variable UAA (kha) is positive but not statistically significant at the 0.05 level, albeit slightly (p = .058).

Analysing the beta standardized coefficients, it is possible to compare the effects of independent variables on the dependent variable (GSP/UAA). LN(VC/UAA) is the variable with the strongest positive effect on the economic performance (beta = ,632) followed by ARB/UAA (beta = ,425): both these variables have a strongly significant effect and play an important role in explaining the variance of the dependent variable. The other three variables have a positive and significant, but less impacting effect on the dependent variable: UAA/TA (beta = ,121), UAA (beta = ,076) and Irrigation (beta = ,072). This evidence can lead us to conclude that Irrigation has a significant role in determining economic performance, but its role is inevitably less crucial than other variables, such as variable costs and type of farming.

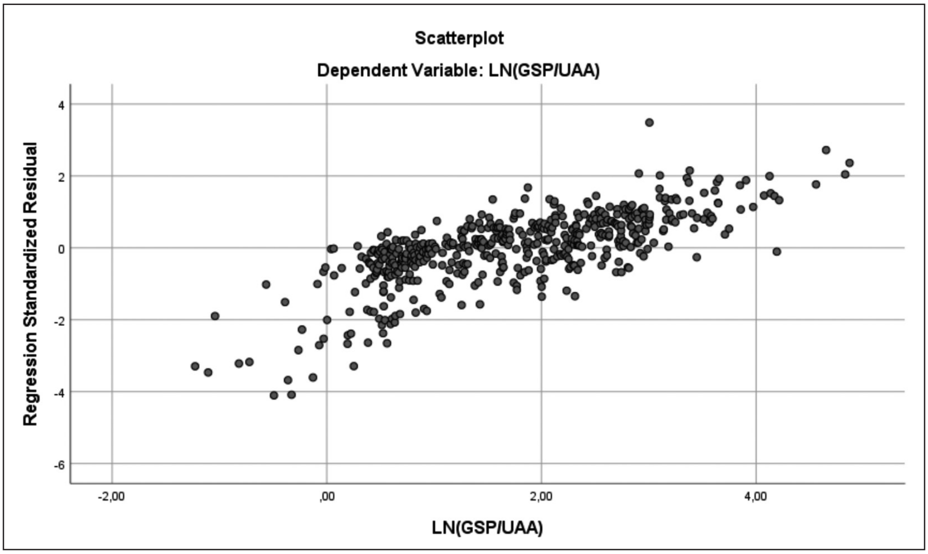
The developed model does not present collinearity problems as the VIF (Variance Inflation Factors) values of the independent variables are close to the unit value. Finally, observing the histogram of standardized residues (Figure 4) and the scatter plot of standardized residues (Figure 5) we can

Figure 4 - Standardized residuals histogram for the model in step 2



Source: our elaboration on FADN data.

Figure 5 - Scatter plot of standardized residuals for the model in step 2



assume that the model has two violations in relation to the assumptions on regression residuals: the distribution is leptokurtic and there is a certain violation of the hypothesis of non-linearity. The authors suggest, for future developments, to introduce additional control variables in order to improve the adaptation of residues and to isolate more precisely the effect that the use of irrigation has on the productivity of farms.

Conclusions

The results obtained from the tests carried out lead to confirm that irrigation positively affects the GSP in the sample considered. This confirms what has already been demonstrated in previous studies concerning the impact of irrigation on the economic performance of farms. The results relating to the control variables considered show that variable costs positively affect the GSP, reflecting the positive impact of input intensity on crop yield.

Furthermore, the results show that even the share of UAA under tree crops have a positive impact on the GSP of the sampled farms. In fact, arboriculture (tree crops) has undergone an increase in recent years in Veneto, mainly because of the good commercial results of the wine sector in some prestigious areas. Veneto leads with other few regions the production of quality wines. Recent experiments in the field of plant protection have allowed the resumption of fruit-bearing productions, such as apple, pear and peach trees. The area used for olive trees is also important, with the production of fine olive oils, confirming that the trend of climate change makes Veneto more and more suitable also for typically Mediterranean crops and dependent on irrigation practice, even if the empirical assessment of the relationship between type of farming and irrigation is not the subject of this analysis. The analyses for the verification of the goodness of fit of the residuals of the model used suggest, however, that the analysis could be refined in the context of future developments, considering additional control variables that might allow to isolate more precisely the effect of irrigation on the productivity of farms.

The results obtained are relevant in the context of water resource management policies, confirming the economic relevance of water for the agricultural sector. The weather-climatic trends and the economic importance of irrigated agriculture make water an increasingly valuable asset for agricultural production. These elements highlight the importance of sustainable water management, an objective pursued by supporting investments to improve the efficiency of farms irrigation systems and, also, by envisaging, within the 2014-2020 Rural Development Programme, a number of interventions for the modernization of infrastructures and the introduction of environmentally sustainable technologies.

The measures to boost efficiency of water use in agriculture certainly have an environmental value, as highlighted by the increasingly ambitious environmental objectives of the Common Agricultural Policy. Results show that a better management of water resources is important not only for the protection of aquatic ecosystems, but also for guaranteeing farms' viability. The analysis does not consider variables related to the efficiency of the use of inputs, including water; this represents a limitation of the analysis and future developments could better investigate this aspect. However, the literature counts several studies that demonstrate the ability of improving efficiency to increase profitability (Wichelns *et al.* 2002; López-Mata *et al.*, 2019). The adoption of technologies to improve the efficiency of water use plays a key role in reducing pressure on water bodies without causing economic losses for farms. This underlines the profound interconnections between the economic and environmental system on which the CAP is based. Moreover, the proposal of the CAP post-2020 regulation is strongly oriented towards promoting environmental protection objectives, while maintaining the objectives of supporting farmers' income. In the specific case of water resources, the provisions laid down by the proposal require to pay particular attention to the coherence between the CAP National Strategic Plan and what is envisaged by the Basin River District Management Plans (RBDPs). Future interventions undertaken under the CAP Strategic Plan and the RBDPs must address both the needs identified by the territorial analysis carried out at district level in relation to the state of water resources and the needs identified for the development of rural areas.

Results show how agricultural policies should continue the effort to improve the efficiency of water use in agriculture, by supporting investments to improve irrigation infrastructures, to spread the adoption of good practices and new technologies at farm level (such as decision support systems to schedule irrigation). These might be complemented by horizontal interventions to promote the access and use of advisory services, training and knowledge transfer actions, that is those measures that might ease the uptake of innovative solutions on farms. The adoption of innovation at farm level appears to be often rather complex, because farmers do not necessarily have access to the new technologies or the technical support they need to transfer them in the field. Already in the current programming, several Regions have used the measures to promote knowledge transfer, advice innovation-related measures for the achievement of water efficiency (focus area 5a).

The future CAP 2023-2027 could offer opportunities in this context, since the Proposal for a Regulation on National Strategic Plans provides for the possibility for Member States to grant support for investments in irrigation in new and existing irrigation systems, taking up many aspects of the current art. 46 of Reg. (EU) 1305/2013. The strengthening of the Agricultural Knowledge and Innovation System, as envisaged by the CAP post-2020, might offer additional opportunities to improve the services to farmers, in terms of access to specialised advice and training, as well as the possibility to cooperate (operational groups or other cooperation interventions) with researchers and other farmers to transfer innovative solutions in the farms.

In order to guarantee sustainable management of water resources, in addition to the aspects covered by this analysis, it is also necessary to reflect on the environmental effects of water use in agriculture, which can be considered both as pressure and benefit, especially in relation to the aquifer recharge processes. In this work, only a part of the effects of water use in agriculture has been analysed, being the main focus on the economic aspects at farm level. The main scope is to provide elements for the assessment of the value of water as an input for agricultural production processes in a context, such as the current one, of significant climate change. The results of the study might raise interest on the implication in terms of overall sustainability of water use, which could become the subject of future development of this work.

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Per la valutazione degli articoli proposti nel 2021, *Economia agro-alimentare/Food Economy* si è avvalsa dei seguenti collaboratori. A tutti loro, vanno i più vivi ringraziamenti del Comitato di Direzione e della Segreteria di Redazione.

Gumataw Abebe (Dalhousie University, Canada), Kehinde Paul Adeosun (University of Nigeria Nsukka, Nigeria), Joni Murti Mulyo Aji (Universitas Jember, Indonesia), Themistoklis Altintzoglou (Nofima, Norway), Filippo Arfini (University of Parma, Italy), Sirak Bahta (International Livestock Research Institute, ILRI, Kenya), Angelo Belligiano (University of Molise, Italy), Aldo Bertazzoli (University of Bologna, Italy), Danilo Bertoni (University of Milan, Italy), Alessandro Bonadonna (University of Turin, Italy), Filippo Brun (University of Turin, Italy), Roberto Cagliero (CREA, Italy), Nicola Cantore (United Nations Industrial Development Organization, Austria), Fabian Capitanio (University of Naples Federico II, Italy), Felicetta Carillo (CREA, Italy), Alessandra Castellini (University of Bologna, Italy), Daniele Cavicchioli (University of Milan, Italy), Marija Cerjak (University of Zagreb, Croatia), Emilio Chiodo (University of Teramo, Italy), Silvia Coderoni (Università Politecnica delle Marche, Italy), Attilio Coletta (University of Tuscia, Italy), Melanie Connor (IRRI - International Rice Research Institute, Philippines), Adele Coppola (University of Naples Federico II, Italy), Stefano Corsi (University of Milan, Italy), Livia Maria Costa Madureira (University of Trás-os-Montes e Alto Douro, Portugal), Maria Crescimanno (University of Palermo, Italy), Richard J. Culas (Charles Sturt University, Austalia), Giorgio De Ros (Edmund Mach Foundation of San Michele all'Adige, Italy), Eugenio Demartini (University of Milan, Italy), Pablo José Moya Fernández (University of Granada, Spain), Mariantonietta Fiore (University of Foggia, Italy), Angelo Frascarelli (University of Perugia, Italy), Roberto Furesi (University of Sassari, Italy), Florence Gachango (Pwani University, Kenya), Francesca Galli (University of Pisa, Italy), Gianluca Gariuolo (CREA, Italy), Rino Ghelfi (University of Bologna, Italy), Roberto Gismondi (Istituto Nazionale di Statistica, Italy), Sabrina Giuca (CREA, Italy), Kannan Govindan (Shanghai Maritime University, China), Jon Hellin (IRRI - International Rice Research Institute, Philippines), Martin Hingley (University of Lincoln, United Kingdom), Stefan Hirsch (Technische Universität München, Germany), Mirjam Holinger (FIBL, Switzerland), Carmen Hubbard (Newcastle University, United Kingdom), Corrado Ievoli (University of Molise, Italy), Drini Imami (Agriculture University of Tirana, Albania), Thomas S. Jayne (Michigan State University, USA), Robert P. King (University of Minnesota, USA), Piermichele La Sala (University of Foggia, Italy), Messaoud Lazereg (Research Center in Applied Economics for Development, Algeria), Fabio Madau (University of Sassari, Italy), Maria Cecilia Mancini (University of Parma, Italy), Andrea Marchini (University of Perugia, Italy)

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ISSN 1126-1668
ISSNe 1972-4802