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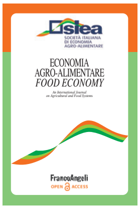

The Role of Neighborhood Effects on Investing Dairy Farms

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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.

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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

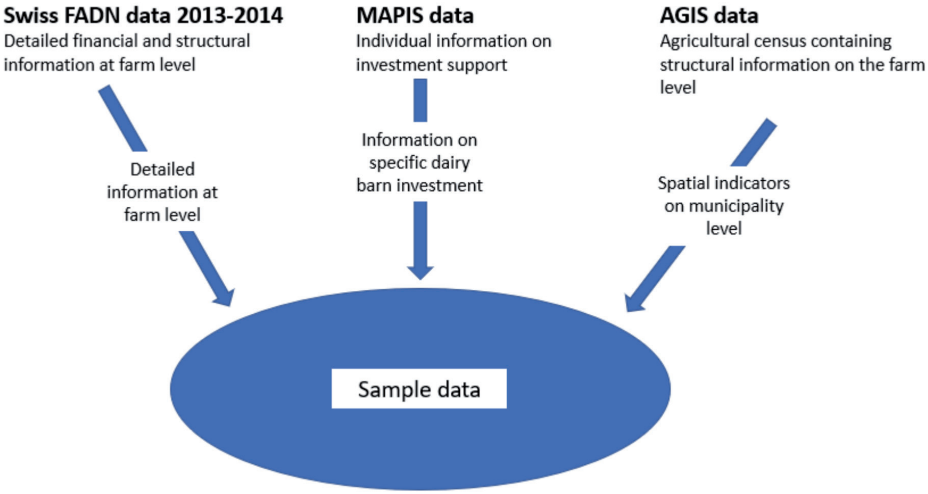
According to government officials from cantonal lending institutions, almost all major projects on dairy barns are supported by interest-free investment credits (Personal Communication, 2017). All projects subsidized by those credits are registered in a central database, the "Meliorations-und Agrarkredit-Projekt-Informationssystem" (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:

$$(3) \qquad X_{i,t} = \alpha + ha\ UAA_{(i,t)}\beta_{ha} + No\ Pro_{(i,t)}\beta_{NoPro} + Gini_{(i)}\beta_{Gini} + Reg_{(i)}\beta_{Reg} + Quota_{(i,t)}\beta_{Quota} + Type_{(i)}\beta_{Type} + Equ_{(i,t)}\beta_{Equ} + Non\ AI_{(i,t)}\beta_{Non\ AI} + \varepsilon_{(i,t)} + \mu_i$$

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:

$$G = \frac{n}{n-1} * \left(\frac{2\sum_{i=1}^{n} i x_{(i)}}{n\sum_{i=1}^{n} x_{(i)}} - \frac{n+1}{n}\right), \quad (4)$$

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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