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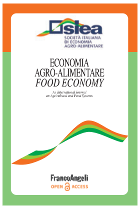

Innovative behavior of family farmers in Brazil in the face of innovations in the agricultural sector

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Abstract

Innovation in family farming plays a critical role in regional economic and social development by introducing new products, technologies, processes, and attitudes. This article aims to evaluate the innovative behaviors of family farmers in southern Brazil concerning agricultural sector innovations. We conducted a quantitative survey of 442 family farmers, employing partial least squares structural equation modeling and multi-group analysis as our analytic methods. Our results reveal both direct and indirect relationships among the dimensions of the innovative behavior scale, tailored to family farming, and the moderating role of organic production on the model. Comparative analysis showed no significant difference in the intensity of the dimensions between organic producers and non-producers. This study offers valuable insights into innovative behavior in family farming, which could inform strategic planning and more effectively direct public policies to support family farmers, ultimately leading to technological advancement and innovation within the sector.

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Introduction

Understanding how family farmers adopt innovation is crucial for improving agricultural policies and development interventions. This research offers socio-economic benefits such as enhanced agricultural productivity, food security, and increased family income (Al-Obadi *et al*., 2022). Understanding farmers' innovative behaviors is essential for the sustainability of the agricultural sector. It promotes the adoption of innovative practices that improve natural resource management and reduce the negative environmental impacts of agriculture (Blakeney, 2022).

Family farming significantly contributes to employment in rural areas, income distribution, social inclusion, and poverty reduction in Brazil. Studying the innovative responses of Brazilian family farmers to agricultural innovations can provide insights into their adaptation to new technologies and practices (Fuestsch, 2022), highlighting the sector's role in socio-economic development (Gonzaga *et al*., 2019; Fernandes & Hallewell, 2016).

Innovation behavior, which involves identifying, articulating, and implementing new ideas to improve performance, can offer competitive advantages (Zhu *et al*., 2022; Jin *et al*., 2022; Walter & Au-Yong-Oliveira, 2022). However, innovation in rural areas faces structural, sociocultural, and psychosocial barriers and challenges in business succession and entrepreneurship within family farming (Tomei & Souza, 2014; Suess-Reyes & Fuetsch, 2016).

Family farmers play a crucial role in food production, supplying a significant portion of the food in large cities. The family farming sector in Brazil contributes notably to agricultural employment and output. Public food purchases, like the National School Feeding Program, are essential for sector development and transitioning to a more sustainable food system (Zahaikevitch *et al*., 2022; IBGE, 2019; Cavalli *et al*., 2020; Gaitán-Cremaschi *et al*., 2022).

This study aims to evaluate the innovative behavior of family farmers regarding agricultural sector innovations, emphasizing the need for public policy actions that meet the realities of family farming. By exploring the innovative behavior of Brazilian family farmers, this research intends to inform strategic actions, contribute to the literature on innovation and rural development, and enhance understanding of innovation generation and adoption in these settings. Innovations that promote resilience in agricultural practices can offer valuable insights into sustainability theory.

The study advances understanding of innovative behavior among family farmers and provides insights for developing public policies that promote sustainable and organic practices. It contributes to the scientific literature on innovation, sustainable rural development, and agricultural public policies.

Despite the relevant role of innovation in the economic and social development of the agricultural sector, family farmers face significant challenges in consistently and effectively adopting innovative practices. The central problem of this study is to understand the factors that influence the innovative behavior of these farmers, particularly in the Brazilian context, where structural, cultural, and market barriers hinder the adoption of new practices and technologies. The lack of understanding of these specific challenges, such as the influence of participatory leadership and external contacts, represents an obstacle to the development of more effective public policies.

Given these challenges, the study aims to investigate the innovative behavior of family farmers within the context of agricultural innovations, focusing on both organic and conventional practices. While innovation is crucial for sustainable development and agricultural competitiveness, research exploring the influence of participatory leadership and external contacts on family farmers' innovative outcomes is limited. This study seeks to offer practical insights for policy formulation and expand knowledge on innovative behavior in rural settings, thus being relevant for both theoretical development and practical applications in innovation and agricultural sustainability programs.

While previous studies have explored innovative behavior in large-scale agricultural sectors, there is a significant research gap concerning family farmers, who play a fundamental role in food security and sustainability in Brazil. Knowledge about the influence of participatory leadership and external networks on the innovative behavior of family farmers remains limited. This study seeks to fill this gap by investigating how these factors contribute to innovation within the context of Brazilian family farmers, providing insights for policies that can boost sustainable and organic practices.

1. Theoretical background and hypotheses

In family farming, participatory leadership involves engaging all family members and possibly other stakeholders in decision-making. This democratic approach ensures that diverse perspectives are considered, leading to more comprehensive and sustainable farming practices.

The proposed relationship (H1) suggests that participatory leadership in family farming significantly influences innovative outcomes. This assumption is based on the idea that the participative and collaborative leadership style, necessitated by family farms' operational and organizational structure, enhances their innovative capacity. By examining the role of participative leadership in family farming, this hypothesis highlights the potential of collaborative decision-making and autonomy in driving innovation in the agricultural sector, especially among small rural producers.

The micro-AKIS approach emphasizes the importance of localized, farmer-centric knowledge and information systems in enhancing agricultural innovation and sustainability. Within this framework, participative leadership plays a key role in creating a micro-environment conducive to innovation among family farmers by facilitating information exchange, knowledge sharing, and fostering trust and engagement among stakeholders involved in agriculture (Madureira *et al*., 2022).

Awang *et al*. (2020) illustrate how participative leadership can make the interaction environment more favorable for generating innovative ideas through improved information sharing and the development of trust-based relationships and engagement at work. This view is consistent with the belief that innovative behavior includes idea generation and the actions necessary for implementation and performance improvement in professional contexts (De Jong & Den Hartog, 2008).

Developing ideas as a precursor to creating new products, services, and processes, which initiate innovation, is fundamental. External contacts are essential catalysts for innovative behavior. By promoting frequent external contact, individuals encounter new stimuli, alternate perspectives, and diverse viewpoints, stimulating creativity and leading to innovation (De Jong & Den Hartog, 2010). This is particularly relevant in agriculture, where exchanging knowledge and practices significantly influences productivity and sustainability.

The micro-AKIS framework underlines the significance of localized and farmer-centric approaches, showcasing the role of participatory leadership in enhancing these external contacts. Participatory leadership broadens the horizon of external contacts by encouraging meetings and interactions within and beyond the farming community, facilitating the flow of information and knowledge crucial for innovation. Thus, the second hypothesis (H2) asserts that participatory leadership greatly affects external contacts, indicating that the leadership style of family farmers can directly impact the extent and quality of their interactions with external stakeholders, forging an environment conducive to innovation.

This hypothesis acknowledges the micro-AKIS approach by emphasizing the role of social and informational networks in agricultural innovation. It suggests that how family farmers lead and engage with their community and external actors significantly affects their ability to innovate and adapt to changes, underscoring the link between leadership, knowledge exchange, and innovation in family farming (Madureira *et al*., 2022). The concept of social capital, defined as the networks of relationships among people in a society that enable it to function effectively, provides a useful perspective for assessing the impact of external contacts on innovation.

Cofrè-Bravo *et al.* (2019) and Vecchio *et al.* (2022) provide insights into how social capital within rural and agricultural communities significantly influences innovative outcomes. These studies suggest that through dimensions such as trust, norms, and networks, social capital facilitates the sharing and exchange of knowledge, resources, and support, which is critical for fostering innovation.

De Jong and Den Hartog (2008) emphasize the importance of social interaction and the exchange of experiences external contacts provide, including relationships with clients, competitors, suppliers, and researchers. Such interactions expose individuals to diverse perceptions and ideas, stimulating creativity and new idea generation, crucial for innovation. However, Lyons *et al.* (2019) note that geographical isolation in rural areas often limits these interactions, highlighting the need to create additional opportunities for family farmers to proactively engage and form connections aligned with their interests.

The challenge in rural areas, marked by geographical distances and infrequent encounters, underscores the importance of leveraging social capital to overcome these barriers. By fostering stronger networks and relationships within and outside the agricultural community, family farmers can access a wider range of external contacts more frequently, enhancing their exposure to new ideas and perspectives that drive innovation.

Therefore, H3 should be refined to incorporate the role of social capital in enhancing the relationship between external contacts and innovative outcomes. Specifically, it suggests that a farmer's social capital quality and extent can moderate the impact of external contacts on innovation, implying that stronger social networks and relationships facilitate greater exposure to diverse ideas and experiences, which, in turn, promotes innovative outcomes. This hypothesis highlights the challenges faced by family farmers due to geographical isolation and proposes a pathway through which these challenges can be mitigated. Enhancing social capital within rural communities can provide a supportive environment for innovation, suggesting that interventions aimed at building and strengthening social networks play a crucial role in enhancing the innovative capacity of family farming.

Participative leadership plays a key role in this process. This leadership style, marked by a collaborative approach to decision-making and a focus on engaging team members in the innovation process, significantly affects the generation of innovative ideas and practices. Alblooshi *et al.* (2021) and Azeem *et al.* (2021) highlight the positive impact of participative leadership on innovation, noting that it promotes skill development, networking, and knowledge exchange. These activities enable family farms to establish and maintain essential external contacts for innovation.

Nonetheless, the relationship between participative leadership, external contacts, and innovative outcomes is complex. Maharous and Genedy (2019) point out that several factors influence this relationship, including organizational culture, technological advancements, and market dynamics. These factors can affect the efficacy of participative leadership in fostering external contacts and, consequently, innovative outcomes. Given these factors, the next hypothesis explores this relationship further: Participatory leadership influences innovative outcomes through external contacts (H2 and H3).

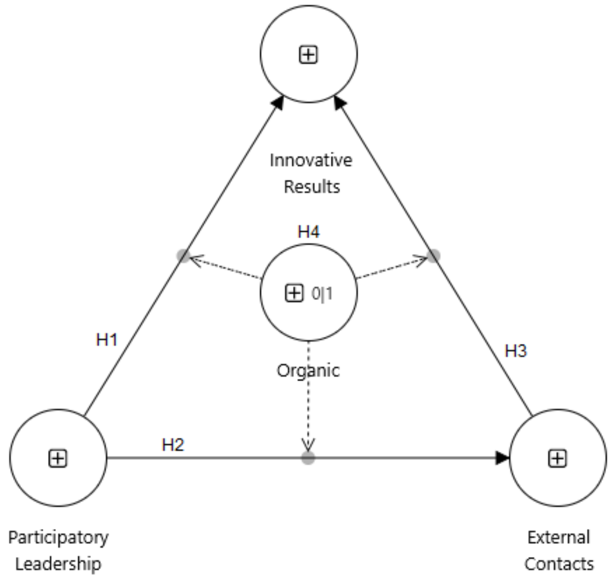
This hypothesis suggests that by enhancing external contacts, participatory leadership plays a crucial role in achieving innovative outcomes in family farming. It asserts that the leadership style within these operations significantly affects the quality and extent of external interactions, which, in turn, drives innovation. The hypothesis aims to examine the mediating role of external contacts in the participatory leadership-innovation relationship, offering a thorough understanding of how family farms can overcome geographical isolation and enhance innovation through strong social capital and participative leadership practices.

The moderating effect of organic production on innovative behavior examines how the choice between organic and conventional farming practices influences the relationship between family farmers' characteristics and their level of innovative behavior. Deciding to adopt organic or conventional methods may alter the strength of the relationship between innovative behavior dimensions.

Thus, exploring the moderating effect of organic production sheds light on the factors that affect innovative behavior and helps producers develop more effective innovation strategies. This focus underscores how specific production practices – organic versus conventional – influence innovation in the family farming sector. The hypothesized relationship should, therefore, make a direct comparison, considering the possible differences in innovative behaviors between organic and conventional producers (Hussain *et al*., 2020; Tandon *et al*., 2021; Marin-Garcia *et al*., 2022). Organic production influences the relationship between scale dimensions (H4).

For a clearer understanding and visualization of these hypotheses and their interconnections, Figure 1 presents the structural model proposed in this study. H1: Participatory Leadership influences Innovative Results. H2: Participatory Leadership influences External Contacts. H3: External Contacts influence Innovative Results. H4: The relationship between Participatory Leadership, External Contacts, and Innovative Results is moderated by the type of production (Organic vs. Conventional).

Figure 1 - The research model of this study



2. Materials and methods

A quantitative study involving 442 family farmers in southern Brazil was conducted from March 2021 to October 2022. This time frame was chosen to gather a robust and reliable sample sufficient for modeling and analyzing results. The study utilized a non-probabilistic, convenience sampling method with data collection at fairs, family farming exhibitions, and direct visits to properties; it adhered to ethical and legal standards, receiving approval from a research ethics committee (opinion no. 4.761.535; CAEE no. 46804621.7.0000.5346). Participants were given a detailed consent form explaining the study's purpose, guaranteed data confidentiality, and assured of their right to withdraw.

The research was carried out in person at family farming fairs (52 cities) and agricultural exhibitions (10 cities) across the three states of southern Brazil: Rio Grande do Sul (RS), Santa Catarina (SC), and Paraná (PR). In RS, data were gathered from 62 municipalities, including feedback from 27 exhibitors in the capital Porto Alegre and 373 exhibitors across 59 other cities. In SC and PR, data collection occurred in the capitals Florianópolis and Curitiba from 14 and 8 exhibitors, respectively. Data collection included the capitals Florianópolis and Curitiba, with 14 and 8 exhibitors, respectively.

These cities were chosen because they are capitals of their respective states, allowing researchers access to farmers participating in family farming fairs in the capitals.

Data collection instrument included a scale with three dimensions to measure innovative behavior: Participative Leaders, adapted from Robbins (2005), Pires *et al*. (2014), and De Jong and Den Hartog (2008); External Contacts, adapted from Pugas *et al*. (2017) and De Jong and Den Hartog (2008); and Innovative Results, adapted from Jong and Hartog (2008) and Axtell *et al*. (2020). These dimensions were contextualized for the rural setting and utilized a 4-point Likert scale (1 = rarely, 2 = sometimes, 3 = often, 4 = always).

For data analysis, descriptive statistics were applied to sociodemographic data, and the score standardization method by Lopes (2018, p. 35) was used to analyze the innovative behavior scale dimensions (Equation 1).

$$Ss_i = 100 * \frac{(Sum - Minimum)}{(Maximum - Minimum)}, \tag{1}$$

where Ss_i is the standardized score for dimension i, Sum is the sum of valid scores for dimension i, minimum is the lowest possible score for dimension i, and maximum is the highest possible score for dimension i. The scores developed by the scale's authors were adapted to a standardized score (Ss_i), as listed in Table 1.

Table 1 - Adaptation of scores originally proposed by the authors of these scales with the standardized score

Score of the original instrument	**Proposed score (Ss_i)**	**Classification**
All dimensions	0.00-20.00	Very low
	20.01-40.00	Low
	40.01-60.00	Moderate
	60.01-80.00	High
	80.01-100.00	Very high

Dimension scores were standardized as very low, low, moderate, high, and very high. This standardization allowed us to develop a model to evaluate the relationships and test the hypotheses outlined using partial least squares structural equation modeling (PLS-SEM). The method followed these steps: a) analysis of the structural model, b) analysis of the measurement model, c) estimation of the path model and evaluation of the measurement model, d) analysis of the moderating variables, e) multi-group analysis, and f) evaluation of the structural model (Hair *et al.*, 2017). Analyses were conducted using the SmartPLS® software (version 4.1.0.5) (Ringle *et al.*, 2022).

To compare dimensions between groups, we applied a normality test to the standardized data (Shapiro-Wilk test). If the data were not normally distributed, we used a non-parametric test, the Mann-Whitney test, to compare two independent groups (Lopes, 2018). The significance level was set at 5%. The SPSS® software (version 26) was used for comparative analyses.

3. Results

Sociodemographic information

Of the 442 farmers surveyed, the mean age was 46 years old, with a standard deviation of 16.64%. The most common age group was over 50, comprising 44.34% of respondents. Most respondents (n = 273; 61.76%) were male, and 95.02% resided in Rio Grande do Sul. Additionally, 163 participants (36.88%) had a high school education, and 315 (71.72%) engaged solely in farming. The survey found that a majority of 234 farmers (52.98%) produced organic products. However, only 28 (6.33%) had certified their products as organic. Furthermore, 252 respondents (57.01%) reported not having any employees, and 246 (55.66%) were members of a producer or credit cooperative, as detailed in Table 2, which outlines the sociodemographic characteristics of the producers.

Model fit tests

The model stabilized after seven iterations. This study employed various criteria to assess the fit of the PLS-SEM, including *standardized root mean square residuals* (SRMR), squared Euclidean distance (d_{ULS}), geodesic distance (d_G), and normed fit index (NFI). The results confirmed that the proposed structural model provided a good fit to the data, with acceptable indices such as SRMR = 0.078, dULS = 0.834, dG = 0.192, and NFI = 0.898 (Henseler *et al.*, 2016). The SRMR value was below the threshold of 0.08 (Henseler *et al.*, 2016), and the NFI value exceeded the recommended threshold of 0.8 (Hu & Bentler, 1998; Stone, 2021), indicating that the structural model is satisfactory and adequate.

Table 2 - Sociodemographic and social characteristics of family farmers (n = 442)

Variables	**n (%)**
Age, mean (SD)	46.01 (16.64)
Residents, mean (SD)	4.31 (5.510)
Age range (years)	
Young (<30)	72 (16.29)
Mature (30–50)	174 (39.37)
Old (> 50)	196 (44.34)
Gender, n (%)	
Female	169 (38.24)
Male	273 (61.76)
Brazilian state, n (%)	
Rio Grande do Sul	420 (95.02)
Santa Catarina	14 (3.17)
Paraná	8 (1.81)
Level of education, n (%)	
High school level	163 (36.88)
Elementary school level	118 (26.70)
Undergraduate level	127 (28.73)
Graduate level	34 (7.69)
Any other professional activity?	
No	315 (71.72)
Yes	125 (28.28)
Do you produce organic products?	
No	208 (47.06)
Yes	234 (52.94)
Are you certified?	
Unemployed	208 (47.06)
Not certified	159 (35.98)
Seeking certification	47 (10.63)
Certified	28 (6.33)
Do you have employees?	
No	252 (57.01)
Yes	190 (42.99)
Are you a member of a cooperative?	
No	196 (44.34)
Yes	246 (55.66)

SD = standard deviation

Measurement model evaluation

The measurement model was evaluated using PLS-SEM, aimed at confirming the hypotheses proposed in the study (Hair *et al*., 2027). Three measurement criteria were assessed: internal consistency analysis, convergent validity, and discriminant validity. The criteria include average variance extracted (AVE > 0.5), Cronbach's alpha, and composite reliability (0.7 < q < 0.95). Discriminant validity was assessed through the Fornell-Larcker criterion and the heterotrait-monotrait ratio (HTMT) using the bootstrapping technique with 5,000 subsamples. For the Fornell-Larcker criterion, a criterion must be abovegiven AVE must surpass the corresponding values in the correlation matrix, and for the HTMT criterion, the upper limits of the estimated HTMT values must remain below 1.0 (Hair *et al*., 2017).

Internal consistency reliability

The internal consistency among the indicators of each dimension was analyzed using CA and CR. Table 3 shows CA values ranging from 0.744 to 0.810 and CR values from 0.789 to 0.863, which are above the minimum threshold of 0.7 and below the maximum of 0.95 (Hair *et al*., 2017). The AVEs ranged from 0.515 to 0.517, aligning with the recommendation that values should exceed 0.5. These indicators confirm the reliability of the internal consistency within the model's dimensions. Additionally, the model exhibits factor loadings (FL) above 0.6.

Table 3 - Model evaluation

Dimensions/indicators	**FL**	**CA**	**CR**	**AVE**
Participatory leadership (PL)		0.786	0.855	0.515
PL01 - Do family, friends, the community in general or other people ask your opinion?	0.824			
PL02 - When they talk to you, do they ask for suggestions on the best way to carry out certain tasks or business?	0.845			
PL03 - Have these people ever consulted you about important changes in their lives?	0.811			
PL04 - Have these people ever allowed you to influence long-term decisions on tasks/business in their lives?	0.792			

PL05 - When you needed them, did they support your decision to set your own goals?	0.670			
PL06 - On your property or when you were in charge of a management position (union or community), were you able to carry out your ideas/tasks with independence and freedom?	0.694			
External contacts (EC)		0.744	0.789	0.517
EC01 - Do you keep in touch with your main customers (those who buy your products)?	0.695			
EC02 - Do you look for new (potential) customers for your products?	0.835			
EC03 - Do you usually attend lectures, courses, trade fairs, and exhibitions?	0.681			
EC04 - Do you often exchange ideas with other producers who sell the same products as you?	0.656			
EC05 - Do you keep in touch with teachers or services offered by any university?	0.601			
Innovative results (IR)		0.810	0.863	0.515
IR01 - How often do you think of new ideas to improve the products you produce?	0.751			
IR02 - How often do you apply these ideas to improve working practices?	0.735			
IR03 - How often do you seek out new knowledge?	0.797			
IR04 - How often do you actively develop new working methods, techniques, or tools?	0.737			
IR05 - How often do you look for new partners to buy/sell inputs/products?	0.689			
IR06 - How often do you optimize the organization of your work?	0.679			

Discriminant validity

Discriminant validity was evaluated using the Fornell-Larcker criterion and HTMT to assess the distinctiveness of a dimension from others, as shown in Table 4 (Fornell & Larcker, 1981). The square root of the AVE for the dimensions was higher than the values in Pearson's correlation matrix. The HTMT criterion's upper limits were below 1.0 (95% confidence), indicating that the discriminant validity between the dimensions fulfilled the established criteria. Consequently, the measurement model's assessments for internal consistency reliability, convergent validity, and discriminant validity were satisfactory, empirically substantiating the appropriateness of the measurement model for the studied model.

Table 4 - Fornell-Larcker and HTMT criterion of the factor model

Dimensions	**Mean**	**SD**	**AVE**	**Pearson's correlation matrix**		
				1	**2**	**3**
1. External contacts	3.63	1.277	0.719	1.000		
2. Innovative results	3.87	1.012	0.718	0.483	1.000	
3. Participatory leadership	3.05	1.192	0.718	0.350	0.380	1.000
				Upper limit (HTMT)$_{97.5\%}$		
2. Innovative results				0.729		
3. Participatory leadership				0.610	0.572	

SD = standard deviation

Structural model, hypothesis testing, and path relationship evaluations

The direct and indirect relationships and moderating effects between the dimensions were assessed using regression coefficients (b) (Table 5). The bootstrapping method was also employed to evaluate the significance of the values (based on the value of using the t-test). According to Hair *et al.* (2017), a path relationship was deemed significant at a 5% significance level when the t-test value exceeded 1.96.

Regarding the primary hypotheses derived from direct relationships, all were confirmed (i.e., H1, H2, and H3), including mediation (H2 and H3). Table 5 indicates that H4, involving organic vs. conventional production, was moderated, necessitating a multi-group analysis (Tables 6 and 7) based on a subsequent hypothesis (H5).

The results of the multi-group analysis (MGA) are presented in Table 6, utilizing the Henseler method (a non-parametric approach) and a permutation test for evaluation. Within Henseler's MGA approach, a $p < 0.05$ indicates significant differences in path coefficients between organic and conventional producers (Lopes *et al.*, 2024).

Table 5 - Results of the direct effects among dimensions

Hyp.	Path relation	β	SD	t-stat.	p-value	Result
H1	PL→IR	0.240	0.047	5.079	0.000	Supported
H2	PL→EC	0.350	0.044	7.920	0.000	Supported
H3	EC→IR	0.399	0.040	9.971	0.000	Supported
H2-3	PL→EC→IR	0.196	0.067	2.965	0.003	Supported
H4a	O*PL→IR	0.053	0.098	0.542	0.588	Not Supported
H4b	O*PL→EC	0.175	0.092	1.902	0.011	Supported
H4c	O*EC→IR	0.172	0.088	1.944	0.006	Supported
H4d	O*PL→EC→IR	0.134	0.048	2.801	0.000	Supported

O = organic; SD = standard deviation.

H5: Organic vs. conventional production differs in the relationships proposed in H1 to H4:
H5-1. Participatory leadership affects innovative results compared to organic vs. conventional producers;
H5-2. Participatory leadership affects the external contacts compared to organic vs. conventional producers;
H5-3. External contacts affect innovative results compared to organic vs. conventional producers;
H5-4. Participatory leadership affects innovative results mediated by external contacts compared to organic vs. conventional producers.

Table 6 - Multi-group analysis results: organic vs. conventional

Hyp.	Path relation	β (O - C)	p-value (difference)		Results
			Henseler's MGA	Permutation test	
H5-1	PL→IR	–0.076	0.504	0.620	No/No
H5-2	PL→EC	–0.117	0.007	0.008	Yes/Yes
H5-3	EC→IR	–0.140	0.004	0.005	Yes/Yes
H5(2-3)	PL→EC→IR	–0.129	0.017	0.020	Yes/Yes

PC = path coefficient.

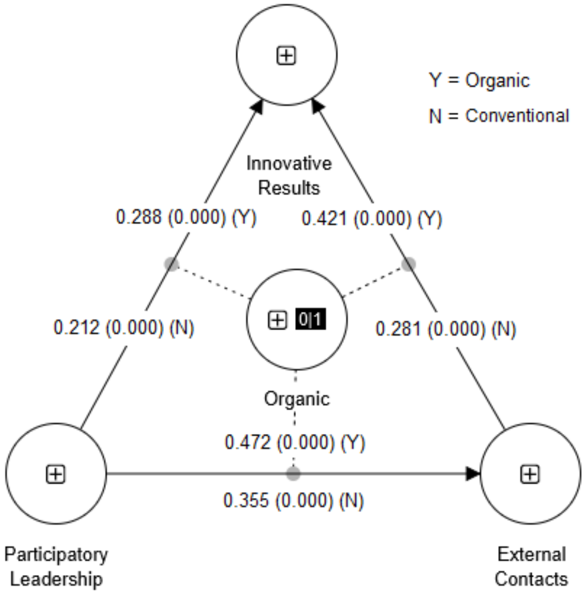
Table 7 and Figure 2 show the analyses that separate the groups and evaluate H6 and H7 by type of producer. Despite differences in the structural coefficients between organic and conventional producers, the model's hypotheses were significant for both groups.

Table 7 - Results of the multi-group analysis among dimensions

Hyp.	**Path relation**	**β**	**SD**	**t-stat.**	**p-value***	**Result**
			Organic			
H6-1	PL→IR	0.212	0.062	3.419	0.000	Supported
H6-2	PL→EC	0.355	0.068	5.221	0.000	Supported
H6-3	EC→IR	0.281	0.057	4.928	0.000	Supported
H6-4	PL→EC→IR	0.128	0.030	4.267	0.000	Supported
			Conventional			
H7-1	PL→IR	0.288	0.072	4.645	0.000	Supported
H7-2	PL→EC	0.472	0.057	8.281	0.000	Supported
H7-3	EC→IR	0.421	0.060	7.017	0.000	Supported
H7-4	PL→EC→IR	0.257	0.032	8.031	0.000	Supported

PC = path coefficient; SD = standard deviation; * p < 0.001

Figure 2 - The final structural equation model



Predictive capability evaluation

One of the important aspects of evaluating a PLS-SEM is to test the model's predictive relevance. Predictive relevance is assessed using the explanation coefficient, which measures the degree of variability in the data accounted for by the endogenous dimensions (Hair *et al*., 2017). According to these authors, the R^2 value ranges from 0 to 1. An R^2 value above 0.19 indicates a high level of predictive accuracy (strong effect), while a value ranging from 0.075 to 0.19 indicates a moderate effect.

Table 8 shows the R^2 values for the External Contacts dimension for organic producers at $R^2 = 0.138$ ($p < 0.001$) and for conventional producers at $R^2 = 0.112$ ($p < 0.001$). This suggests a moderate predictive accuracy for both groups, with organic producers exhibiting 2.6% more predictive power. For the Innovative Results dimension, organic producers had an $R^2 = 0.389$ ($p < 0.001$), and non-producers an $R^2 = 0.312$ ($p < 0.001$), indicating a high level of predictive accuracy; organic producers had 7.7% more predictive power (Henseler *et al*., 2009; Lopes *et al*., 2020; Obregon *et al*., 2024).

Another method for assessing the predictive relevance of a structural model is by calculating Q^2 using the blindfolding technique in SmartPLS® software. This technique allows the endogenous dimensions to predict future values based on the information provided by the exogenous dimensions (Fang *et al*., 2022). Following the recommendations of Hair *et al*. (2017) and Lopes *et al*. (2020), a Q^2 value greater than 0.075 indicates that the model's predictions are reliable. The statistical results demonstrated that all the Q^2 values for each dimension are significant (Table 8), with $Q^2 > 0.075$, underscoring the predictive relevance of the proposed model.

Table 8 - Evaluation of predictive accuracy and predictive relevance

Predictive dimension	**Organic**		**Conventional**	
	R^2 (p-value)	**Q^2**	**R^2 (p-value)**	**Q^2**
External contacts	0.138 (0.000)	0.121	0.112 (0.000)	0.086
Innovative results	0.389 (0.000)	0.116	0.312 (0.000)	0.155

Table 9 presents the normality test results for the dimensions using the Shapiro-Wilk test. The scale (innovative behavior) exhibited normal distribution ($p > 0.05$), while the dimensions did not ($p < 0.05$). Consequently, we employed the Mann-Whitney non-parametric test to compare the groups of organic and conventional producers. The analysis revealed no significant differences in the scale and dimensions of innovative behavior between the two types of producers (p > 0.05).).

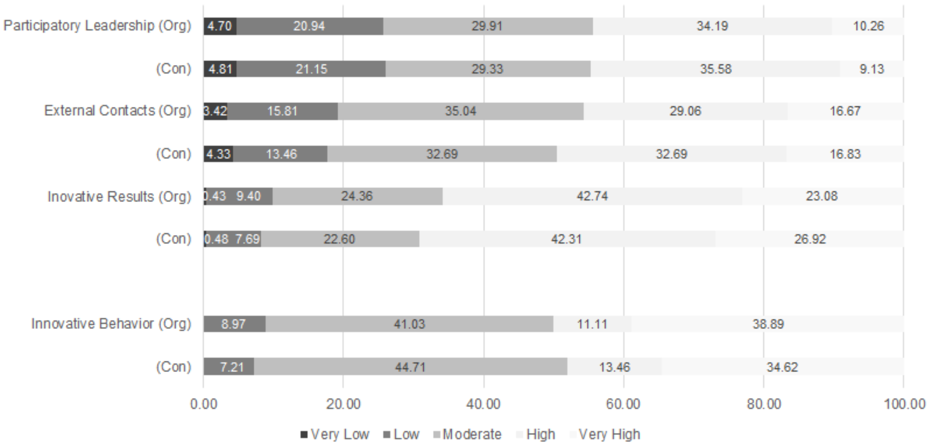
Table 9 - Comparative test of standardized dimensions between producers

Dim.	**Organic (n = 234)**			**Conventional (n = 208)**			**Mann-Whitney test**
	Normality test*	**Mean**	**SD**	**Normality test***	**Mean**	**SD**	
EC	0.013	58.82	21.366	0.003	59.67	22.163	0.539
PL	0.018	54.55	20.997	0.029	55.58	20.098	0.459
IR	0.006	66.18	18.447	0.001	67.89	18.185	0.539
IB	0.586	61.11	15.300	0.303	62.29	14.955	0.362

* Shapiro-Wilk test; SD = standard deviation; IB = innovative behavior.

The characteristics associated with innovative behavior are illustrated in Figure 3. This figure indicates that 50.00% of organic producers and 48.08% of conventional producers exhibit high levels of innovative behavior. Specifically, of the producers surveyed, 217 (49.10%) demonstrate high innovative behavior, 197 (44.57%) exhibit high participatory leadership, 210 (47.51%) have frequent external contact, and 298 (67.42%) achieve high levels of innovative results.

Figure 3 - Classification of innovative behavior of producers



4. Discussion

The findings of this study align with and extend prior research on innovative behavior and leadership in the context of family farming and rural development. De Jong and Den Hartog (2010) emphasized the critical role of participatory leadership in fostering innovative work behavior. Consistent with their conclusions, our study confirms that family farmers exhibiting participatory leadership are more inclined towards engaging in innovative practices, leading to improved product development and process innovation outcomes. Additionally, this study supports the significance of external interactions, showing that external contacts markedly influence innovation outcomes, particularly in agricultural settings.

Previous research highlighted the importance of external contacts in promoting innovation. Cofré-Bravo *et al.* (2019) found that social capital, especially through external networks, plays a vital role in innovation among farmers. Our findings corroborate this, demonstrating that family farmers who actively engage with customers, suppliers, and other external agents gain better access to innovative ideas and practices. This underlines that innovation capacity is not solely reliant on internal leadership but also effective interactions with and learning from external sources.

The influence of organic farming practices on innovative behavior has also been documented. Marin-Garcia *et al.* (2022) discovered that organic farming systems enhance innovative outcomes due to the unique challenges and knowledge exchange required in sustainable farming. Our study reinforces this argument by indicating that organic farmers, compared to conventional farmers, benefit more from participatory leadership and external contacts, resulting in higher innovation rates. Madureira et al. (2022) further emphasize the importance of localized, farmer-centric knowledge systems (micro-AKIS) in promoting innovation and sustainability, noting that these systems support organic farmers by fostering tailored knowledge exchange and strengthening community-based networks, which are essential for overcoming the specific challenges of organic production.

Our findings revealed a slight predominance of family farmers who produce organic products without the help of an employee. A minority of these farmers are certified, albeit they are cooperative members, which ends up helping them somehow. Organic production, a product without chemical pesticides and with management that does not harm the local ecosystem, has been growing considerably. In 2020, production grew by 30%, but the number of registered family farmers is still small, with around 25,000 registered with the responsible body (Ministério da Agricultura, Pecuária e Abastecimento, 2021).

Moreover, it was possible to identify a relationship between the dimensions of innovative behavior, namely participative leadership, external contacts, and innovative results, within a sample of family farmers. The results indicate that participative leadership affects innovative results (H1), which shows that farmers whose characteristic is participative leadership with openness to new ideas and suggestions from other people may increase engagement and favor the creation of a fertile environment for innovative ideas and, consequently, innovative results (Awang *et al*., 2020). It should be noted that the farmer's profile differs from other groups of entrepreneurs, as they have characteristics that are peculiar to their working environment, so the way they lead differs from the conventional leader since, in the family environment, this hierarchy is not present (Tomei & Souza, 2014).

Since leadership in the family farming environment is still considered a barrier or challenge to the development of rural entrepreneurship (Tomei & Souza, 2014), it is important to identify those who indicate that they have these characteristics and seek to develop this potential to develop family farming as a whole (Souto & Brose, 2022). This corroborates H2, which identified that participatory leadership affects external contacts; this means that in the same way that leadership can provide innovative results, it also affects the farmer's relationship with people, groups, or cooperatives and events outside their daily life, facilitating the exchange of experiences and contact with different products, actions, and activities, expanding their knowledge and their network of contacts. Hence, this can bolster the development of their products and the creative process in search of innovation (Jong & Hartog, 2010), a fact that was verified when supporting H3, which identified the relationship between external contacts and innovative results.

Furthermore, these dimensions are completely linked to the innovative behavior of family farmers, and H2-3 demonstrates this relationship. External contacts mediate the relationship between participatory leadership and innovative results, showing that there is a relationship in which participatory leadership, through engagement and collaboration between farmers in the same family, has a positive impact on the innovative results mediated by the external contacts made by the farmer, reinforcing the understanding of Alblooshi *et al*. (2021).

Chen *et al*. (2016) reported that social relationships between members of the same work team, in this case, adapted and considered members of the same family, and with external individuals and bodies, provide information, insight, experience, and conversations that increase knowledge and, therefore, help develop organizational innovation. This reinforces the importance of developing participatory leadership, which allows the people who work alongside the farmer to participate in decisions, motivating them, instigating creativity, and ultimately driving innovation since people will feel part of that environment (Azeem *et al*., 2021).

Of the hypotheses tested regarding the moderating effect of the variable ‘organic producers’, three out of four proposed hypotheses were confirmed. The relationship between participative leadership and external contacts, the relationship between external contacts and innovative results, and the mediation of external contacts in the relationship between participative leadership and innovative results showed a moderating effect on the organic production variable. The other moderating variables (gender and age) did not significantly differ in the innovative behavior of the rural producers surveyed.

A multi-group analysis was conducted to assess the difference between organic and conventional producers (i.e., H5), revealing that H5-2, H5-3, and H5(2-3) confirmed significant differences in the structural coefficients of the model between organic and conventional producers (Table 6).

Differences between organic and conventional producers have been highlighted in various studies, demonstrating that organic farmers often possess unique characteristics that influence their approach to innovation and production. Mazzoleni and Nogueira (2006) found that organic producers tend to have higher educational levels and are more likely to employ updated technologies and modern management tools, such as digital software for tracking and optimizing farm activities. Similarly, Marin-Garcia *et al.* (2022) emphasize that the unique demands of organic farming push these producers toward sustainable innovations, which are supported by continuous knowledge exchange within organic farming communities.

Saénz *et al.* (2024) identify that external relational capital, especially horizontal and vertical connections, plays an essential role in promoting innovation on organic farms. The study observes that relationships with knowledge institutions, such as universities and research centers, as well as with governmental associations, enhance the capacity for innovation in production processes and methods, which is particularly relevant in the organic context. Through these connections, farmers not only gain access to advanced technologies but also strengthen practices of social learning and knowledge co-creation, which are fundamental for overcoming the sustainability and productivity challenges characteristic of organic agriculture.

Aghabeygi *et al.* (2024) underscore that organic farmers are often more inclined to adopt sustainable soil management practices, encouraged by supportive policy incentives and certification programs. These external supports play a critical role in offsetting economic and technological barriers, which are particularly challenging in organic systems. Such programs provide financial resources, knowledge sharing, and technical assistance, making it feasible for organic farmers to implement practices that enhance soil health, improve biodiversity, and align with ecological goals. Consequently, this policy support not only fosters environmental sustainability but also enhances the economic resilience of organic farming by reducing dependency on synthetic inputs and promoting a circular approach to soil fertility and crop health.

These distinctions suggest that organic producers, through continuous engagement with both agricultural and non-agricultural networks, cultivate an environment more receptive to adopting sustainable practices and innovations, as compared to their conventional counterparts. This alignment with broader networks and higher education levels provides organic farmers with greater resources to navigate the unique challenges of organic agriculture, contributing to their capacity for adaptive and innovative practices.

Given the above, when we carried out a separate analysis (Table 7), we found that organic producers had more significant structural coefficients, as seen in Figure 2. When we analyzed the predictive capacity of the models, we observed that for organic producers, the external contacts dimension is 2.6%. The innovative results dimension is 7.7% higher in predictive power (Table 8).

Other researchers have also reported other differences. Mazzoleni and Nogueira (2006) identified differences between producers certified to produce organic products and those in the certification process, namely in education levels, hired labor, and use of technology, highlighting that certified farmers more frequently utilize up-to-date techniques and tools, including Microsoft Excel. Notably, 65% of certified farmers versus 35% of non-certified farmers indicated involvement in other professional activities, supporting our findings regarding external contacts. In addition, 50% of organic producers exhibit a high potential for innovative behavior compared to 48% of non-organic producers (Figure 3). In the dimensions of the scale, the innovative results dimension stood out, with 74% of organic producers demonstrating high behavior compared to 69% of non-organic producers.

This study confirms and corroborates other research on the relationship between participatory leadership, external contacts, and innovative results, proving that participatory leadership influences innovative results and is mediated by external contacts (Pugas *et al*., 2017). Leadership is essential in driving innovation (Alblooshi *et al*., 2021), and in this study, as it is a sample of farmers with their particular work characteristics, it is understood that rural producers will play the role of the leader and that sometimes there will be no leaders but rather members of the same family. In this sense, the farmer's role as a leader will be demonstrated by encouraging and promoting innovation in the workplace, which is crucial for developing the property, region, and organic production domestically and through exports (Lima *et al*., 2020).

The theoretical implications include identifying differences in innovation behavior between organic and conventional family farmers, suggesting that the working context influences their perspectives and behaviors regarding innovation. This is vital for understanding family farmers' characteristics, addressing the data gap on this subject, and assisting in developing targeted programs and public policies aimed at family farmers to promote innovation adapted to their specific needs (Cele & Wale, 2020).

Conclusions

The research aimed to assess the innovative behavior of family farmers in the context of agricultural sector innovations, providing insights relevant for shaping public policies and development strategies for family farming. The key findings illustrate a complex interplay between participatory leadership, external contacts, and innovative outcomes, emphasizing the role of social capital and networking in fostering innovation within this sector.

A significant finding is the slight predominance of family farmers engaging in organic production without employee assistance. Despite a low certification rate among these producers, their membership in cooperatives provides support, highlighting the benefits of collective action and shared resources in overcoming innovation barriers and market access challenges. The 30% increase in organic production in 2020 suggests a significant shift towards sustainable farming practices, although the number of registered family farmers remains small. This gap between adopting organic practices and formal certification suggests policies are needed that simplify the certification process and support organic farming expansion.

The study's findings on participatory leadership, external contacts, and innovative results suggest these elements collectively contribute to the innovative behavior of family farmers. Participatory leadership, characterized by openness to new ideas and collaborative decision-making, not only facilitates innovation but also enhances the farmer's ability to form beneficial external contacts. These external relationships, in turn, act as conduits for new ideas, knowledge exchange, and innovative outcomes. However, the role of organic production as a moderating variable shows that the farming context can significantly affect these dynamics.

The low certification rate among organic producers highlights a challenge in the development and innovation process within family farming. The bureaucracy and difficulties associated with certification deter many farmers from formalizing their organic practices, limiting their market access and benefits. This underscores the need for policy interventions to reduce these barriers and encourage broader participation in organic farming.

The research emphasizes the critical role of government support policies, regulations, and social functions in facilitating innovation within family farming. By providing more data on this farmer group, the study contributes to targeted strategies for investment and research to enhance the sector's innovation capacity. Strategies could include subsidizing new technology adoption, offering training programs, investing in research and development, and promoting rural entrepreneurship and economic diversification.

In conclusion, this study identifies critical factors influencing the innovative behavior of family farmers and offers evidence-based recommendations for public policies supporting organic production, simplifying the certification process, and promoting sector innovation. By addressing the unique challenges faced by family farmers, especially those engaged in organic farming, these policies can contribute to a more sustainable, productive, and resilient agricultural sector.

Limitations and recommendations for future research

Despite the relevance and quality of the information generated, this study has its limitations. One such limitation is its lack of focus on a single group of producers according to their production specialty. Instead, it encompasses a diverse group, including pluri-active family farmers and producers involved in various crops. Another limitation is the need to adapt the questionnaire for a rural audience, which involved simplifying the vocabulary and eliminating ambiguous interpretations.

The research methodology employed was non-probabilistic convenience sampling. This method was chosen for its practicality and ease of accessing and engaging with participants. Data collection took place in environments where family farmers are most active and accessible, such as agricultural fairs, family farming exhibitions, and direct visits to farming properties.

For future research, we recommend evaluating monoculture producers, assessing innovation behavior in specific niches, and exploring the impact of additional variables not examined in this study. Furthermore, research should include those who are difficult to reach, such as producers not involved in farmers' markets or related activities. These individuals often miss out on the exchange of information that can enhance knowledge and tend to be more isolated in terms of external contacts.

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