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Gendering the digital transition among farms facing constrained institutional contexts

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Abstract

This paper investigates gender dynamics in the adoption of digital innovations in agriculture, focusing on the Comino Valley, a remote rural area of Italy characterized by constrained institutional contexts. Adopting a constituent perspective on women's role in agriculture, the study conceptualizes women as entrepreneurial agents within innovation decision-making processes. The analysis examines digital adoption pathways through the lens of social capital, emphasizing the reconfiguration of relational architectures based on ambidexterity among bonding, bridging, and linking ties. Drawing on survey data from 342 farms, the empirical evidence suggests a potentially relevant tension between observed innovation outcomes and the differentiated mechanisms through which such outcomes are achieved. While no statistically significant gender gap emerges in overall digital innovation adoption, women farmers operate smaller and less capitalized farms and report lower self-assessed entrepreneurial identity. At the same time, women exhibit higher engagement in bridging and linking social capital related to digital innovation. These findings suggest that comparable innovation outcomes may coexist with differentiated relational strategies, through which women adapt to structurally constrained environments. The paper contributes to the literature on gender, rural entrepreneurship, and digital transition by highlighting how processes of relational reconfiguration and compensatory adaptation may support women farmers in achieving innovation outcomes comparable to those of their male counterparts under constrained institutional conditions.

Keywords Gendering innovation, Remote rural areas, Constrained institutional context, Relational ambidexterity

Introduction

The role of women in farming has attracted increasing scholarly attention in recent decades. A substantial body of literature highlights women's contributions to sustainable rural development, socio-economic resilience, and food security in both developed (Shortall 2025; Vuciterna et al. 2024; De Rosa and McElwee 2021; De Rosa et al. 2019; Morgan et al. 2010) and developing economies (Cheong et al. 2025; Quisumbing et al. 2022; Ghouse et al. 2021; Lourenço et al. 2014). Achieving gender equality (in rural areas) is a policy issue that has long been debated in the literature (Shortall and Marangudakis

2024). The relative lack of focus on support for women in the rural policy process is also recognized as being a significant issue (Cheong et al. 2024). However, there appears to be a new focus at least in the European Union to address this significant issue, as shown in the EU Gender Equality Strategy 2020–2025¹, aimed to encourage women's participation in the agricultural sector. Along similar lines, the new EU Vision for Agriculture and Food (European Commission 2025) emphasises the necessity to attract women to farming, and to ensure fair living and working conditions for them. Moreover, as pointed out by Casares Guillén and Pazos Vidal (2025), the 2023–2027 CAP marks a paradigm shift through its new delivery model. It introduces the possibility of incorporating gender equality measures within CAP Strategic Plans, under Specific Objective 8 (SO8)², which promotes gender equality, employment, and social inclusion in rural areas. Many opportunities to support women farmers are scheduled, such as³:

- Investments into infrastructure and services – enablers of social inclusion of women.
- Provision of incentives for local employment opportunities for women.
- Enhanced support and incentives for female farmers.
- Improving the access to loans for women for entrepreneurial activities.
- Empowering women in decision making.

Despite various policy interventions, numerous constraints still hamper women farmers' entrepreneurial activities (Amato et al. 2025). These challenges warrant further investigation, with a specific focus on supporting women's activities within remote rural contexts. The contribution of women to boosting sustainable transition in these areas deserves attention; their roles must be recognized and rewarded (Shortall and Marangudakis 2022), particularly regarding their influence on the innovation adoption process.

This paper points out that women have differing access to key resources, such as technology dissemination (Njuki et al. 2022) and emphasises the relevance of networking and social capital (Seuneke and Bock 2015) in analysing the entrepreneurial mechanisms behind the digital and sustainable transition in remote rural areas through a gender-based lens. Within this perspective, social capital, entrepreneurial identity, and dynamic capabilities are treated as interconnected relational mechanisms through which women farmers navigate constrained institutional environments.

Sustainable transitions challenge previously consolidated frames of reference (widely shared representations of the world) and institutional structures (established and “embedded” set of institutions, techniques, practices, and routines) (Angeon and Crevoisier 2024). In particular, literature has emphasized the “disruptive” nature of digital technologies (Klerkx and Rose 2020), and the barriers to adopting digital solutions, while, at the same time, evidencing also the role of context-enabler played by digital solutions (Rijswijk et al. 2021). On the other hand, the role of digitalization is pivotal to boost sustainable transition in rural areas (Brunori 2024; Arcuri et al. 2023). Nonetheless, rural areas are identified as unconducive environments, on account of the physical and cultural barriers characterizing the entrepreneurial activity (Gittins et al. 2025). Moreover, digitalization may create new constraints, on account of emerging new skills

¹ Gender equality strategy - European Commission.

² https://agriculture.ec.europa.eu/common-agricultural-policy/cap-overview/cap-glance/key-policy-objectives-cap-2023-27_en.

³ https://eu-cap-network.ec.europa.eu/news/women-new-cap_en.

and the needed technological infrastructure, that is the minimum technological requirements for adopting a digital innovation (Lioutas and Charatsari 2022).

Our paper adopts a constituent perspective of women farmers (Whatmore 1993) in boosting digital innovation and confirms a women-led innovation perspective (Farrell et al. 2024) that is drawn on an entrepreneurial process of building up new gender-based relational architectures. Our analysis is grounded in the hypotheses of ‘visible participation’ (Little and Panelli 2003), wherein the decision-making process falls entirely under women’s responsibility (Adinolfi et al. 2020). Adopting a constituent perspective, this paper frames women’s entrepreneurship as an emancipatory act that fosters empowerment (Hughes et al. 2012), in a context of willing reproduction (Heather et al. 2005). More precisely, the paper tries to fill a gap in literature, by treating the rural context as a Constrained Institutional Context, within which entrepreneurial processes of relational reconfiguration become necessary to support innovation adoption in fragile rural areas. Starting from the idea that digitalization is deemed a facilitator to address gender inequalities in rural areas (Comfort Akello and Brunori 2025), we put forward a gender-based analysis of the uptake of digital solutions in rural areas identified as Constrained Institutional Contexts (CIC). However, despite increasing attention to women-led innovation and digital transitions in agriculture, limited research has investigated how women farmers redesign relational architectures to navigate constrained institutional contexts in remote rural areas. More precisely, the paper investigates the role of relational architecture in shaping the adoption of digital solutions. With this purpose, the paper focuses on socially constructed relations, such as networks, reciprocal trust, shared social norms, synthesized by the concept of social capital (Putnam et al. 1993).

Social capital has gained momentum in rural development studies. Nonetheless, we believe that gender issues and gender relations deserve more attention to better investigate social capital in rural contexts. Framed within an entrepreneurial perspective, the paper aims to provide an original contribution by investigating the relational architectures women entrepreneurs develop to adopt digital solutions.

The paper is structured as follows: the next section provides an evolutionary perspective of the role of women in farming. The purpose is not to provide an exhaustive literature review, but to focus on the emergent strategies carried out by women in rural areas, meant as constrained institutional contexts. Section 3 presents the methodology of analysis located in a remote rural context of Italy, where women farmers are engaged in processes of twin transition (digital and sustainable). Section 4 illustrates the empirical results, while the final section discusses the findings and outlines policy conclusions.

Theoretical background

The role of women in agriculture has been widely analysed in the literature (Vuciterna et al. 2024; Little 2006). We identify two main strands in the literature:

- 1) *The first strand concerns the evolution of women’s agency in farming, which has developed through three main stages:*
 - a. Co-workers. The first one characterizes the 1970s and identifies women as coworkers helping male farmers (Berg 2004).

- b. Increasing Visibility. The work of Whatmore (1994) points to a higher visibility of women in the farming activity, whose role is linked to income integration objectives (Unay-Gailhard and Bojnec 2021).
 - c. Self-Reliant. A third configuration pinpoints women farmers as “reliant” entrepreneurs. This perspective considers women as entrepreneurs, whose decision-making process is nonetheless influenced by other male family members (Shortall 2002), within dynamics of co-preneurship (Dyer et al. 2013; De Rosa et al. 2021a, b).
- 2) *Emergent perspectives that underline the entrepreneurial dimension of women in agriculture in recent decades:*
- d. Some scholars highlight how women gained a better status (Charatsari 2014), while others have depicted women farmers as “pure” entrepreneurs (Brandth 1995, 2002), especially within the theoretical strand of radical subjectivism, according to which decision-making is assumed as individual, under processes of willing reproduction (Heather et al. 2005). In this backdrop, framed within an opportunity enactment perspective, women may exploit opportunities embedded in socially constructed environments (Alsos et al. 2011).

This paper is situated within this latter perspective, recognizing heterogeneity and flexible gender identities as key concepts in rural gender studies (Albornoz-Arias et al. 2025; Rao 2025; Bock and Shortall 2017). It shares the idea that *‘because gender relations are complex and vary across contexts, nuanced and context-specific data collection and analytical methods are recommended, often involving both qualitative and quantitative methods in the same study’* (Quisumbing and Doss 2021, p.4483). Within this standpoint, scholars have shown that female farmers pursue agricultural practices distinctly different from male farmers (Schmidt et al. 2021). Distinctiveness emerges with particular reference to women’s ability to foster the transition towards multifunctional agriculture (Seuneke and Bock 2015; Zirham and Palomba 2016; Little and Panelli 2003) and to act as better stewards of the environment (Doss et al. 2018). Furthermore, women’s role in rural economies through entrepreneurship, agricultural practices and farm diversification is now well documented (Farrell et al. 2024; Bradshaw et al. 2017). This configuration has been consolidated within the recent Feminist Agrifood System Theory (FAST), theorized by Sachs et al. (2016). According to this new vision, women farmers set themselves apart from male farmers and play a key role in building up sustainable farming systems (Tsiaousi and Partalidou 2023). As a consequence, *‘value-added agriculture especially, and some forms of sustainable agriculture, creates the context for the implementation of knowledge and labor practices more likely to be considered part of women’s socio-cultural toolkit’* (Wright and Annes 2020, p.379).

Starting from the perspective of women farmers as entrepreneurs (McElwee 2006), this paper analyses women-led digital innovation adoption in rural areas. As highlighted by Farrell et al. (2024, p.569): *‘Women-led innovations are processes led by women, that seek novel economic, social, technological, environmental, political, and/or institutional solutions, and that are embedded in societal contexts, which can block or/and enable collective female agency’*. Azima et al. (2025) emphasize how women farmers are motivated by strong social and agroecological values, but they are constrained by a gendered entrepreneurial ecosystem acting as barriers (cultural, financial, etc.) to entrepreneurship.

Accordingly, we set the women farmers' activity against a context-related analysis (Welter 2011), by framing this activity within an ever-shifting *Constrained Institutional Context* (CIC) (Gittins et al. 2022). Constrained entrepreneurship is a relatively recent field of analysis through which agricultural entrepreneurship is explored (Refai and McElwee 2022), with the purpose of pointing out the influence of formal and informal institutional barriers affecting the entrepreneurial activity (Gittins and McElwee 2023).

Gittins et al. (2022) define CIC as a '*complex system of actor network relationships affected by changes in the institutional environment, which can create constrained contexts for individuals and power-struggle relationships between certain actors. These relationships often empower certain actors, granting them control over valuable resources, while oppressing others*'.

With reference to gender issues, various constraints must be considered: the first one concerns spatial constraints and refers to the remoteness of rural areas (Gittins and McElwee 2025). The remoteness causes a set of constraints, synthesized by the vicious circle of rural areas (European Commission 2008), such as the lack of infrastructure and services in rural areas, which may bring about lower business opportunities. Moreover, the lack of basic services (health assistance, education, etc.) may discourage women farmers' activity, due to the overlap between the productive and reproduction spheres (Doss and Gottlieb 2025; Errington and Gasson 1993). Indeed, for women managing a family farm business, the intersection of the domestic sphere with productive work in areas lacking essential services (such as education and health care) can increase pressure on their ability to carry out agricultural work.

Another dimension identifying a constrained (gender-based) institutional context concerns the presence of locally embedded and prevailing informal institutions in a male-dominated sector. Institutions are defined by Scott (1995, p.13) as '*cognitive, normative, and regulative structures and activities that provide stability and meaning to social behavior. Institutions are transported by various carriers—culture, structures, and routines—and they operate at multiple levels of jurisdiction*'. An abundant literature has evidenced issues of scarce 'visibility' of women in agriculture, deeply ingrained in cultural norms that relegate them to a marginal role.

This type of social constraint identifies what Gittins et al. (2022) defines the farmer's 'iron cage', which represents a cultural barrier to women entrepreneurship in farming. Consequently, due to the women's role in boosting sustainable transition, Henrotte and Van den Broeck (2026) warn that masculine social norms may reinforce conventional practices and limit the transition. Consequently, a relevant issue concerns how women farmers navigate and address the constraints associated with the farmer's 'iron cage' through processes of "institutional selection" (Hodgson 2003).

A final dimension of constraint regards innovation, especially digital innovation promoted inside dynamics of twin transition (Brunori 2022). These new technologies are emerging as potentially disruptive and can reshape agrifood systems and innovation paths in rural areas (Klerkx 2020). The disruptive nature of digital innovation impacts the knowledge sources required to exploit the opportunities of new digital solutions. These solutions are rooted in diverse networks and activities, giving rise to distinct spatial and digital affordances (Autio et al. 2017). As a matter of fact, in order to adopt digital technologies, it is necessary to verify how spatially dispersed knowledge is mobilized and anchored in territorial rural systems within combinatorial knowledge dynamics

(Jeannerat and Crevoisier 2016), which brings about redesigning the relational architecture through ambidexterity. According to Cofré-Bravo et al. (2019, p. 60) ambidexterity is the '*ability to manage different types of social capital to fulfill different tasks and objectives within the innovation process, i.e. both exploration and exploitation of new technologies and practices*'. The relevance of ambidexterity in cutting-edge innovations is also underlined by Turner et al. (2017), pointing out that the process of innovation adoption should rely on strategic ambidexterity, grounded on the capability of combining previously existing with new sources of knowledge.

Therefore, digital (disruptive) innovations may reshape relational configurations (Rolandi et al. 2021), potentially contributing to more balanced relational architectures (Cofré-Bravo et al. 2019; De Rosa et al. 2024). The capability of balancing relational configurations can be triggered by the mediating actions of advisory services, serving as essential actors within interactive models of innovation adoptions (Arzeni et al. 2023; Masi et al. 2022; SCAR 2019; Klerkx et al. 2012). However, building a balanced relational configuration may be affected by gender-based variables, bringing about differentiated paths of relational assets and, consequently, differentiated entrepreneurial identities. Framed within the context of "gendering innovation" (Kingiri 2013), this paper investigates how women-led innovations redesign relational architectures. If, on the one hand, digitalization is considered a key element for filling the gender gap, on the other hand, literature posits women-led innovation as a distinct kind of innovation (Farrell et al. 2024). As a matter of fact, recent studies have demonstrated gender differences in adopting digital solutions on farms (Paunović et al. 2024; Belas et al. 2025; Tufa et al. 2022). However, less attention has been devoted to investigating the relevance of a constrained institutional context in redesigning the relational architecture to boost innovation adoption. This paper tries to fill this gap by assuming that digital transitions boost new entrepreneurial models characterized by the changing locus of entrepreneurial opportunities, the change of entrepreneurial practices (Autio 2017), and the change of relational architectures. This process becomes particularly complex in cases of twin transition, where digital and sustainable innovations overlap (Brunori 2022). These twin transitions unfold within constrained institutional contexts that may either facilitate or hinder innovation adoption (Gittins and McElwee 2023; Gittins et al. 2022), depending on the effectiveness of knowledge transfer and innovation adoption mechanisms.

Faced with mounting pressures limiting the farmers' room for manoeuvre (Methorst et al. 2017), farmers must develop an entrepreneurial mindset to remain resilient in a highly unpredictable market (Gittins and McElwee 2025). Therefore, how women farmers react and counterbalance the constraints deserves attention and is analysed in our paper through the lens of social capital. More precisely, drawn on the concept of social capital, this paper focuses on social networks as key dimensions of social capital with the purpose of answering the following question by Meinzen-Dick et al. (2014): '*Are there gender-specific barriers to acquiring social capital?*'. As underlined by McElwee and Bosworth (2010), networking is an entrepreneurial skill shaping the farmer's behaviour, jointly with dynamic capabilities (Teece 2007), and the entrepreneurial identity of women farmers, which involves (Vesala et al. 2007) economic values, such as proactiveness, innovativeness, and risk-taking, and individual values, such as self-efficacy, optimism, and personal control.

Accordingly, the paper aims to analyse:

- a. The relational assets women farmers make use of in case of the introduction of digital solutions.
- b. Potential differences in the relational architecture that male and female farmers use to gather information and boost adoption of digital solutions, jointly with their entrepreneurial identity.

Therefore, the research question is:

RQ - What relational configurations characterize women farmers' adoption of digital solutions within constrained institutional contexts?

The underlying hypothesis is that, within the interactive model of innovation (Cruz et al. 2021; Arzeni et al. 2023), different relational configurations and entrepreneurial identities are associated with differentiated patterns of digital innovation adoption across gendered entrepreneurial contexts.

Materials and methods

Study area

The research methodology is grounded in a case-study approach (Yin 2018), focusing on the digital innovation adoption within the Comino Valley, a remote rural area located in Southern Lazio, Italy. More precisely, we conduct an explanatory and not just a descriptive case-study to provide answer to either “how” question, regarding the entrepreneurial process of relational reconfiguring by women farmers adopting digital solutions (Yin 2018). The case-study is of importance within the processes of sustainable and digital transition, from two points of view. First, because Comino Valley is recognized as an internal area within the National Strategy for Internal Areas, with dramatic systemic fragility (Cardillo and De Felice 2022). Second, because Comino Valley is officially recognized as a “Food Biodistrict”, joining farmers adhering to organic methods of productions, who contribute to raise the levels of sustainability and to strong multifunctionality (Wilson 2008) of the agricultural sector. This region, nestled near the central Apennines, is characterised by a diverse agricultural landscape that fosters a robust tradition in cereals, vines, olive groves, and livestock farming, predominantly goats and sheep. Examining digital adoption in this context provides critical insights into how localised knowledge ecosystems influence technological transitions in rural, tradition-bound areas.

Data collection and survey design

The study adopted a purposive stratified sampling strategy aimed at capturing the heterogeneity of the agricultural system within the Comino Valley rural area. In particular, the sample was constructed to include three categories of farms: (i) farms actively participating in the local Biodistrict network, (ii) organic farms operating within the Comino Valley but not formally participating in the Biodistrict, and (iii) non-organic farms operating within the same territorial context. This approach was intended to ensure the representation of the different productive and organizational profiles characterizing the local biodistrict reality and the broader rural system. Accordingly, the sample should be interpreted as analytically representative of the diversity of the local farming system rather than statistically representative of the wider regional agricultural population.

Primary data were collected through a structured questionnaire administered to a sample of 342 farms (198 male-led; 144 female-led). The survey has been conducted between September 2024 and March 2025. The survey was designed to explore how trust and knowledge-sharing networks reshape the farm’s relational architecture in the uptake of digital solutions. With this purpose, the questionnaire was structured into four thematic sections:

1. *Social Capital and Knowledge Networks*: Following Woolcock and Narayan (2000) and Cofré-Bravo et al. (2019), we assessed the importance of actors as knowledge sources (5-point Likert scale; 1=less important to 5=most important) for both ordinary activities and digital innovation adoption. The hypothesis is that as farmers transition from ordinary activity to innovation, their relational architecture evolves toward ambidexterity. Relations among actors were categorised into *Bonding* (strong, localized ties, as relatives, friends), *Bridging* (horizontal professional ties, e.g., local associations, other producers, consultants), and *Linking* (vertical institutional ties, such as university, research centres, banks, suppliers) relations. The following scheme classifies the three types of social capital. The relevance of each type of relationship is determined by the mean score reported for each relation.

Source of social capital	
Types of relations	Proxy for
Family members / friends	<i>Bonding ties</i>
Other farmers in the same area	
Other farms or processing industries or trade companies	
Private or public farm advisors	<i>Linking ties</i>
Banks and other formal institutions (universities, regional organisations, chamber of commerce, etc.)	
Farmers’ organizations	

Source: Adapted from Cofré-Bravo et al. (2019)

2. *Trust*: Respondents rated their trust in different institutions (e.g., political bodies, private companies, research institutions, consultants) on a 5-point Likert scale (1 = no trust to 5 = maximum trust).
3. *Agency and Managerial Competencies*: This section evaluated Entrepreneurial Identity (proactiveness, risk-taking, innovativeness, self-efficacy, optimism, personal control) and Dynamic Capabilities (sensing, seizing, and transforming digital opportunities), drawing on Vesala et al. (2007) and Teece (2007). The internal consistency of these scales was validated using Cronbach’s Alpha (0.89 and 0.84, respectively).
4. *Socio-Demographic and Structural Attributes*: Data included gender, age, education, family composition, Utilised Agricultural Area (UAA), and Standard Output (SO).

Level of digital innovation

The Level of Digital Innovation classifies farms into three tiers based on technological complexity:

- *High Level*: Advanced technologies such as drones, sensors (e.g., radio collars for biometric monitoring, vineyard monitoring), traceability software, and highly automated systems (e.g., automated olive mills, remote-controlled winemaking).

- *Medium Level*: Intermediate solutions like weather stations, basic radio collars, general management software, or semi-automated equipment (e.g., tractors with semi-automatic guidance, semi-automated feeding systems, tanks with semi-automated temperature control).
- *Basic Level*: Farms that have not yet implemented the specific digital innovations under study.

Data analysis

The analytical framework followed a three-step sequential approach to ensure a robust investigation of gender-based disparities. Initially, a comprehensive descriptive analysis was conducted for the entire sample ($N=342$) to establish the baseline characteristics of the agricultural holdings in the Comino Valley. The sample was then disaggregated by gender (198 men, 144 women). Independent samples t-tests (for continuous variables) and Chi-squared tests (for categorical variables) were employed to identify significant differences in social capital endowments, entrepreneurial identity, and digital knowledge. This step was crucial to highlight the “structural suspects” that might drive the innovation gap. Based on the significant differences identified in the bivariate analysis, we moved beyond simple mean comparisons by adopting the Blinder-Oaxaca decomposition (Blinder 1973; Oaxaca 1973). This allowed us to distinguish between differences attributable to structural endowments and differences associated with the heterogeneous returns to these characteristics across groups. Indeed, this econometric technique allows for the partition of the innovation gap between Group 1 (Male) and Group 2 (Female) into two distinct components:

- The Explained Component (Endowments): This measures the portion of the gap attributable to differences in observed characteristics (e.g., education, farm size, social capital levels).
- The Unexplained Component (Coefficients): This represents the portion of the gap due to differences in the returns to these characteristics. In gender studies, this component may, in some contexts, reflect heterogeneous returns to observed characteristics associated with institutional or relational dynamics.

The decomposition is mathematically expressed as:

$$\Delta \bar{Y} = \left[\left(\bar{X}_1 - \bar{X}_2 \right) \beta_1 \right] + \left[\bar{X}_2 (\beta_1 - \beta_2) \right]$$

where $\Delta \bar{Y}$ is the mean innovation score gap, X represents the vector of covariates (endowments), and β represents the estimated coefficients (returns) for each group. The first term on the right-hand side represents the explained component (endowment effect), while the second term represents the unexplained component (coefficient effect). All statistical analyses were performed using STATA 18.

Results

The empirical findings from the survey of 342 agricultural holdings in the Comino Valley, comprising 198 male-led and 144 female-led farms, provide a comprehensive overview of the intersection between gender, social capital, and digital transition within a constrained institutional context.

The initial socio-demographic characterisation reveals significant differences in farm structures (Table 1). While age and educational attainment remain largely homogeneous across the sample, female respondents are more likely to operate within family units involving children (52.08%) compared to their male counterparts (42.93%, $p < 0.10$). This higher domestic integration may reinforce structural constraints associated with the overlap between productive and reproductive spheres, potentially limiting the time and resources available for technological scouting and reinforcing the overlapping of productive and reproductive spheres. Furthermore, a pronounced economic disparity is evident in the Standard Output (SO) distribution; male-led farms demonstrate a significantly higher presence in the upper economic tiers, particularly in the €100,000–€500,000 range, whereas female-led enterprises are predominantly clustered in the lower to mid-range categories ($p < 0.10$). This suggests that women often manage ‘structural laggards’, smaller farms with less capital to invest in cutting-edge technologies.

Despite these structural disadvantages and the restrictive nature of the CIC, the analysis of digital innovation levels reveals an interesting pattern: the Chi-squared test (3.77,

Table 1 Farmer & farm characteristics by gender

	Sample		Male		Female		Chi Squared
	Freq.	%	Freq.	%	Freq.	%	
Age							
Under 40	132	38.60	79	39.90	53	36.81	0.50
41–64	161	47.08	90	45.45	71	49.31	
Over 65	49	14.33	29	14.65	20	13.89	
Educational level							
Middle School Diploma	133	38.89	77	38.89	56	38.89	4.33
High School Diploma	153	44.74	82	41.41	71	49.31	
Laurea or post-Laurea	56	16.37	39	19.70	17	11.81	
Family Composition							
Single individuals	130	38.01	87	43.94	43	29.86	8.67 *
Couple without children	28	8.19	12	6.06	16	11.11	
Couple with children	160	46.78	85	42.93	75	52.08	
Single parent with children	11	3.22	7	3.54	4	2.78	
Family with 2 or more nuclei	13	3.80	7	3.54	6	4.17	
Family Members Working in the Farm							
0	151	44.15	89	44.95	62	43.06	1.82
1	124	36.26	75	37.88	49	34.03	
2	57	16.67	29	14.65	28	19.44	
More than 2	10	2.92	5	2.53	5	3.47	
Utilized Agricultural Area (UAA)							
Less than 5	85	24.85	48	24.24	37	25.69	5.02
5–10	88	25.73	52	26.26	36	25.00	
10–20	65	19.01	37	18.69	28	19.44	
20–50	57	16.67	28	14.14	29	20.14	
50–100	35	10.23	24	12.12	11	7.64	
More than 100	12	3.51	9	4.55	3	2.08	
Standard Output (SO)							
Up to €8,000	37	10.82	22	11.11	15	10.42	10.61 *
€8,000 - €25,000	110	32.16	59	29.80	51	35.42	
€25,000 - €50,000	132	38.60	73	36.87	59	40.97	
€50,000 - €100,000	46	13.45	28	14.14	18	12.50	
€100,000 - €250,000	13	3.80	12	6.06	1	0.69	
€250,000 - €500,000	4	1.17	4	2.02	0	0.00	

Level of significance: * 10%; ** 5%; *** 1%

Table 2 Level of innovation by gender

Innovation Level	Sample		Male		Female		Chi Squared
	Freq.	%	Freq.	%	Freq.	%	
Basic	208	60.82	118	59.60	90	62.50	3.77
Medium	84	24.56	45	22.73	39	27.08	
Advanced	50	14.62	35	17.68	15	10.42	

Level of significance: * 10%; ** 5%; *** 1%

Table 3 Level of knowledge of digital innovations

	Sample		Male		Female		t-test	
	Mean	SD.	Mean	SD.	Mean	SD.		
Weather stations	3.15	0.96	3.19	0.99	3.09	0.92	0.92	
Semi-automated equipment and/or machinery	3.10	0.99	3.21	0.98	2.94	0.97	2.45	**
Management software	3.15	0.96	3.19	0.94	3.10	0.98	0.84	
Radio collars	2.85	1.09	2.90	1.08	2.78	1.10	1.06	
Drones	2.87	1.06	2.86	1.06	2.87	1.06	-0.04	
Advanced sensors	2.97	1.01	3.04	0.98	2.88	1.05	1.39	
Highly automated systems	2.82	0.99	2.90	0.95	2.72	1.04	1.75	*
Traceability software	2.90	1.00	2.98	0.97	2.80	1.04	1.65	*

Level of significance: * 10%; ** 5%; *** 1%

Table 4 Social capital

	Sample		Male		Female		t-test
	Mean	SD.	Mean	SD.	Mean	SD.	
Ordinary Activities							
Bonding	3.37	0.81	3.36	0.81	3.38	0.82	-0.23
Bridging	3.37	0.66	3.33	0.61	3.43	0.71	-1.39
Linking	3.18	0.87	3.12	0.86	3.25	0.87	-1.30
Digital Innovations							
Bonding	3.31	0.84	3.28	0.85	3.36	0.82	-0.84
Bridging	3.40	0.72	3.32	0.73	3.50	0.69	-2.21
Linking	3.12	0.93	3.04	0.93	3.23	0.92	-1.85

Level of significance: * 10%; ** 5%; *** 1%

$p > 0.10$) indicates no statistically significant gender gap in the final adoption of technology (Table 2).

However, female respondents report significantly lower objective knowledge (Table 3) of high-automation systems ($p < 0.10$) and semi-automated machinery ($p < 0.05$). This pattern reflects some of the informational asymmetries characterizing constrained institutional contexts.

The divergence in social capital strategies further underscores this gendered response to digital innovation (Table 4). While social capital dimensions for ordinary activities show no gendered variation, women exhibit significantly higher reliance on bridging capital (3.50 vs. 3.32, $p < 0.05$) and linking capital (3.23 vs. 3.04, $p < 0.10$) specifically for digital innovations. This suggests that female entrepreneurs may engage more intensively in the development of relational assets to navigate institutional voids, relying on external networks as adaptive mechanisms within contexts characterized by lower economic scale and structural support.

This is further reflected in their trust profiles (Table 5), where women report significantly lower trust in private companies (3.55 vs. 3.72, $p < 0.10$). In a context where

Table 5 Trust by gender

	Sample		Male		Female		t-test
	Mean	SD.	Mean	SD.	Mean	SD.	
Interpersonal trust	3.50	0.83	3.56	0.82	3.42	0.85	1.45
Policy institutions	3.02	0.94	3.07	0.98	2.94	0.89	1.22
Local authorities	3.19	0.98	3.19	0.99	3.19	0.96	-0.02
Local community	3.43	0.89	3.46	0.92	3.39	0.86	0.77
Civil society	3.48	0.93	3.53	0.95	3.42	0.89	1.00
Private corporations	3.64	0.92	3.72	0.92	3.55	0.91	1.68 *
Research institutions and Universities	3.62	0.87	3.67	0.85	3.56	0.88	1.17
Farmers	3.74	0.82	3.77	0.83	3.69	0.81	0.87
Producers' associations	3.60	0.87	3.58	0.90	3.63	0.87	-0.45
Advisors	3.85	0.85	3.87	0.82	3.81	0.89	0.60

Level of significance: * 10%; ** 5%; *** 1%

Table 6 Entrepreneurial identity

	Sample		Male		Female		t-test
	Mean	SD.	Mean	SD.	Mean	SD.	
Self-categorization	3.64	0.82	3.74	0.81	3.50	0.81	2.68 ***
Self-efficacy	3.79	0.89	3.88	0.88	3.67	0.88	2.12 **
Optimism	3.86	0.81	3.97	0.82	3.72	0.77	2.91 ***
Personal control	3.97	0.80	4.08	0.81	3.82	0.76	2.97 ***
Risk-taking	4.11	0.79	4.23	0.74	3.95	0.84	3.23 ***
Growth-orientation	3.75	0.90	3.87	0.88	3.58	0.90	2.98 ***

Level of significance: * 10%; ** 5%; *** 1%

Table 7 Dynamic capabilities

	Sample		Male		Female		t-test
	Mean	SD.	Mean	SD.	Mean	SD.	
I am able to recognize the opportunities and threats that arise from digitalization.	3.67	0.81	3.77	0.80	3.54	0.81	2.56 ***
I am able to seize the opportunities of digitalization while maintaining and improving essential skills.	3.89	0.80	3.96	0.78	3.78	0.82	2.06 **
I am able to implement significant changes in my company to adapt to the digital innovations emerging around me.	3.85	0.81	3.98	0.75	3.67	0.85	3.53 ***

Level of significance: * 10%; ** 5%; *** 1%

private firms are the primary purveyors of digital solutions, this lack of trust creates a friction point that requires women to rely even more heavily on their bridging and linking networks for validation and support to mitigate the risks associated with the digital transition.

Some effects potentially associated with the 'iron cage' emerge in the cognitive and psychological dimensions of the transition, where gendered social norms appear to limit the internalisation of entrepreneurial agency. Female farmers score significantly lower across every facet of entrepreneurial identity (Table 6), including self-categorisation, risk-taking, and growth orientation ($p < 0.01$).

These psychological hurdles directly impair their dynamic capabilities (Table 7); women feel significantly less equipped to recognise (3.54 vs. 3.77, $p < 0.01$), seize (3.78 vs. 3.96, $p < 0.05$), or implement (3.67 vs. 3.98, $p < 0.01$) digital opportunities.

The results of the Blinder-Oaxaca decomposition (Jann 2008), employed to examine the nuances of the innovation gap between male-led (Group 1) and female-led (Group

Table 8 Blinder-Oaxaca decomposition

	Coef.	S.E.	p-value
Overall			
Group 1 - Male	1.58	0.06	0.000
Group 2 - Female	1.48	0.06	0.000
Difference	0.10	0.08	0.213
Explained	0.11	0.05	0.037
Unexplained	-0.01	0.08	0.901
Explained			
Digital Innovations_Bonding	0.00	0.01	0.609
Digital Innovations_Bridging	0.05	0.03	0.096
Digital Innovations_Linking	-0.01	0.02	0.553
Entrepreneurial Identity	0.03	0.03	0.343
Dynamic Capabilities	0.02	0.03	0.353
Educational level_Diploma	-0.04	0.03	0.170
Educational level_Laurea	0.04	0.02	0.081
UAA_From 5 to 10	0.00	0.00	0.933
UAA_From 10 to 20	0.00	0.00	0.891
UAA_From 20 to 50	-0.03	0.03	0.189
UAA_From 50 to 100	0.01	0.01	0.360
SO_€8,000 - €25,000	0.00	0.01	0.749
SO_€25,000 - €50,000	0.00	0.01	0.735
SO_€50,000 - €100,000	0.00	0.00	0.845
SO_€100,000 - €250,000	0.04	0.02	0.046
Unexplained			
Digital Innovations_Bonding	-0.24	0.36	0.505
Digital Innovations_Bridging	-0.76	0.62	0.223
Digital Innovations_Linking	1.03	0.39	0.008
Entrepreneurial Identity	-0.14	0.56	0.809
Dynamic Capabilities	0.46	0.53	0.388
Educational level_Diploma	0.23	0.09	0.008
Educational level_Laurea	0.04	0.03	0.207
UAA_From 5 to 10	0.01	0.05	0.903
UAA_From 10 to 20	-0.07	0.05	0.165
UAA_From 20 to 50	-0.03	0.05	0.608
UAA_From 50 to 100	0.02	0.03	0.494
SO_€8,000 - €25,000	-0.01	0.09	0.932
SO_€25,000 - €50,000	-0.02	0.12	0.853
SO_€50,000 - €100,000	-0.03	0.04	0.484
SO_€100,000 - €250,000	0.01	0.01	0.445
Constant	-0.50	0.53	0.342

2) farms, are presented in Table 8. The descriptive mean for the male cohort stands at 1.58, while the female cohort exhibits a mean of 1.48. Although male-led farms show a nominally higher innovation score, the raw difference of 0.10 is not statistically significant ($p = 0.213$). Consequently, the data confirms a substantial convergence in innovation outcomes across gender lines within the sampled population.

However, the detailed decomposition provides a more complex perspective. The aggregate explained component reaches statistical significance (0.11, $p = 0.037$). This indicates that the observed innovation gap, while non-significant in its total raw value, is systematically driven by disparities in structural endowments. Specifically, the innovation advantage of the male cohort is significantly bolstered by organisational size ($p = 0.046$), where larger standard outputs (€100,000 - €250,000) facilitate higher innovation rates.

Marginal effects are also observed for higher education ($p = 0.081$) and bridging social capital ($p = 0.096$), suggesting that male-led farms benefit from a slightly superior baseline of formal qualifications and external network breadth.

Despite these structural advantages favouring male-led farms, the unexplained (coefficients) component of the Blinder–Oaxaca decomposition is not statistically significant, indicating no systematic gender differences in the average returns to observed characteristics. This suggests that female-led farms do not face lower overall conversion efficiency of resources into innovation outcomes. Nevertheless, some heterogeneity emerges at the level of individual coefficients, notably for linking social capital, which exhibits a significant differential in estimated returns. While this finding should be interpreted with caution, given the non-significance of the aggregate unexplained component, it may point to gender-differentiated relational mechanisms rather than structural discrimination. Indeed, the positive and significant coefficient suggests that, with equal linking ties, male-led farms benefit from a more efficient conversion into tangible innovation outcomes.

Overall, the results highlight a form of compensatory adaptation, whereby women-led farms achieve innovation outcomes comparable to their male counterparts despite less favourable structural endowments.

Discussion and conclusions

This study investigated the adoption of digital innovations by women farmers in the agricultural sector of the Comino Valley, a remote rural context of Italy.

This study presents some limitations. First, the analysis focuses on a specific territorial and institutional setting, which may limit the external validity of the findings. Future research should explore whether similar gendered dynamics emerge in different institutional regimes, such as Northern European agricultural systems or emerging economies.

Second, the cross-sectional nature of the data prevents causal inference. Longitudinal designs would be particularly valuable to assess whether the patterns identified here persist over time and whether the reliance on relational strategies evolves as digital technologies become more standardized and less dependent on vertically structured networks. Moreover, future analyses could consider comparing farms of similar size and capital endowment in order to better understand whether this difference persists under comparable structural conditions.

Despite these limitations, the paper contributes to the investigation of the gender-based mechanisms of redesigning relational architectures within the dynamics of digital innovation adoption. This objective has been pursued through:

- a. A constituent perspective on women's role in farming, which rejects a subordinate view of women in the family farm business;
- b. A framing of women's entrepreneurial activity within a constrained institutional context, referring to the remoteness of rural areas and to socio-cultural barriers widely explored in the literature.

Moreover, drawing on literature on rural entrepreneurship, the analysis extends beyond purely economic determinants by incorporating entrepreneurial identity and dynamic capabilities, thereby capturing both structural and psychological dimensions of innovation adoption. By focusing tightly on the interplay between multidimensional social capital (bonding, bridging, and linking) and localized institutional constraints,

the study aims to reconcile traditional agricultural economics frameworks with the relational dimensions of innovation.

The empirical evidence suggests a potentially relevant tension between observed innovation outcomes and the differentiated mechanisms through which such outcomes are achieved. Descriptive results indicate substantial convergence in digital innovation outcomes between male- and female-led farms, a finding confirmed by the absence of a statistically significant gender gap in the overall innovation index. At the same time, women farmers exhibit relatively higher engagement in bridging and linking social capital activities related to digital innovation, while reporting lower levels of self-assessed entrepreneurial identity and dynamic capabilities across all dimensions considered. While these descriptive differences must be interpreted with caution due to their marginal statistical significance, they collectively point toward an exploratory trend: comparable observed innovation outcomes may coexist with gender differences in the relational mechanisms mobilized to achieve them.

The Blinder–Oaxaca decomposition analysis provides additional elements for interpreting these empirical patterns. Although no statistically significant gender gap emerges in aggregate innovation outcomes, the explained component of the decomposition is significant, indicating that male-led farms benefit from more favourable structural endowments, particularly in terms of farm scale, educational attainment, and access to bridging networks. In contrast, the unexplained component is not statistically significant, confirming that there are no systematic, unobserved gender differences in the average returns to these characteristics in our sample. Given the non-significance of the net gap, these findings should not be interpreted as evidence of direct discrimination, but rather as an indication of alternative strategies among women farmers operating under comparatively less favourable structural conditions.

Within this framework, the differentiated reliance on social resources can be understood through the lens of relational mechanisms. Women's greater reliance on digital bridging and linking capital, combined with lower average entrepreneurial identity scores, suggests that women may rely more intensively on social resources to achieve comparable outcomes. This pattern can be interpreted as a form of compensatory adaptation and is consistent with previous studies suggesting that the adoption of cutting-edge innovations is associated with a reconfiguration of relational architectures grounded in ambidexterity (Henrotte and Van den Broeck 2026; Cofré-Bravo et al. 2019; De Rosa et al. 2024). In this perspective, innovation projects require forms of strategic ambidexterity capable of combining the exploitation of existing networks with the exploration of new relational configurations to access, combine, create, or disconnect capabilities (Turner et al. 2017). Accordingly, entrepreneurial opportunity development emerges as a non-linear and iterative process shaped by continuous interaction with heterogeneous network actors.

From an institutional perspective, these dynamics resonate with what Gittins et al. (2022) define as the farmer's 'iron cage', a Weberian constraint where masculine social norms and institutionalised roles shape access to legitimacy and recognition within agricultural systems. Even when women successfully navigate the hierarchy to establish linking capital, the institutional framework may limit the effective conversion of these relational resources into fully recognised innovation advantages. As Henrotte and Van den Broeck (2026) warn, such masculine social norms may reinforce conventional

practices and actively limit the sustainable transition by diminishing the marginal returns of female relational labour. In this sense, the apparent convergence in innovation performance could be interpreted as a sign of institutional progress. However, through the lens of normative isomorphism (DiMaggio and Powell 1983; Meyer and Rowan 1977), this may reflect forms of institutional standardization in which similar aggregate outcomes coexist with differentiated relational patterns and entrepreneurial experiences.

Escaping this 'iron cage' requires more than individual agency; it necessitates dynamics of 'institutional selection' (Hodgson 2003), where the environment itself must evolve to select for diverse entrepreneurial path-dependencies rather than reproducing institutional conditions that may require women farmers to rely more intensively on relational strategies to achieve comparable outcomes. Within this interpretation, women's stronger reliance on relational strategies may be interpreted as an adaptive response to institutional constraints that remain unevenly distributed across gendered entrepreneurial contexts.

The policy implications emerging from the analysis are linked to the differentiated mechanisms through which women farmers achieve innovation outcomes. The evidence suggests that traditional 'gender-blind' innovation policies may inadvertently reinforce existing disparities by overlooking the differentiated pathways through which women achieve innovation outcomes. To break the 'iron cage', a fundamental shift in the design of knowledge transfer mechanisms, through the Agricultural Knowledge and Innovation Systems (AKIS), is required. Within this perspective, advisory services may play a crucial mediating role in reducing the relational and institutional frictions emerging in constrained rural contexts. Their function extends beyond the transfer of technical knowledge, encompassing trust-building, network activation, and the facilitation of women farmers' access to heterogeneous knowledge sources and institutional actors. In particular, advisory systems embedded within AKIS dynamics may help women farmers strengthen the effective conversion of bridging and linking social capital into tangible innovation opportunities. Rather than focusing exclusively on generic technical training (since women already display comparable innovation outcomes despite lower self-assessed entrepreneurial resources), policy interventions should aim at fostering gender-sensitive mentorship networks that facilitate the effective conversion of linking capital into tangible economic outcomes.

Furthermore, funding agencies and local authorities should reconsider standardized evaluation criteria that may overlook structural heterogeneity among farms. Such criteria should explicitly account for the structural disadvantages associated with farm scale and the 'double burden' of domestic integration, ensuring that smaller female-led holdings are not systematically penalized by rigid, one-size-fits-all requirements. The finding that women farmers achieve comparable innovation levels despite lower structural endowments and lower entrepreneurial self-assessment suggests that non-technical constraints may still shape participation in innovation processes. From this perspective, rural development policies could also consider complementary social infrastructure measures, including rural childcare services, to reduce indirect barriers to entrepreneurial engagement.

Finally, the empirical evidence indicates that women farmers rely more intensively on relational mechanisms to access innovation opportunities; consequently, policy interventions should facilitate stable networking environments through cooperative

structures, peer-learning initiatives, and localized innovation support services. These structures can reduce the individual transaction costs women face when scouting for technology and negotiating with private providers, a sector where female trust is currently significantly lower. By complementing individual capacity-building with measures aimed at improving the institutional and relational conditions of innovation access, the agricultural sector may foster more inclusive innovation environments capable of recognizing entrepreneurial potential across different gendered contexts.

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Author contributions

T.P. Conceptualization, Investigation, Data curation, Methodology, Writing – original draft, Writing – review & editing. C.C., E.L. and G.M. Investigation, Writing – original draft, Writing – review & editing. M.D.R. Conceptualization, Project administration, Funding acquisition, Supervision, Investigation, Writing – review & editing. All authors read and approved the final manuscript.

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Data availability

The datasets used and analysed during the current study are available from the corresponding author on reasonable request.

Declarations

Ethical approval

Participation in the survey was voluntary and anonymous. Respondents were informed about the objectives of the study and consented to participate. No sensitive personal data were collected, and no formal ethical approval was required according to national regulations.

Competing interests

The authors declare no competing interests.

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