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Bianchi, Carlos
Galaso, Pablo
Maio, Sofía
Palomeque, Sergio

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Collaboration strategies for digitalization in the Uruguayan forestry industry: a social network analysis

Carlos Bianchi (*), Pablo Galaso (**), Sofía Maio (***), Sergio Palomeque (****)

Resumen

En este artículo se analiza la adquisición de TIC avanzadas en el sistema territorial de innovación de la industria forestal y ecoturismo en Uruguay, considerando tanto a las empresas como a las organizaciones de apoyo relacionadas a estos sectores. Mediante análisis de redes sociales, identificamos que las empresas desarrollan diferentes estrategias de colaboración, las cuales generan resultados colectivos distintos, implican costos individuales variables y requieren capacidades empresariales diversas. Empleando indicadores de centralidad de las redes, identificamos que las empresas llevan a cabo dos tipos de estrategias de colaboración distintas: "intermediario" (centralidad de intermediación) y "bien conectado" (centralidad de vector propio). La estrategia de "intermediario" refleja una posición central en la red asociada a un rol de nexo entre terceros, lo que puede implicar costos para quien la desempeñe. En cambio, la estrategia de "bien conectado" captura una posición altamente conectada en la red, pero sin los costos de actuar como intermediario. Estimamos los efectos de ambas estrategias de colaboración sobre la probabilidad de adoptar TIC avanzadas. Los resultados muestran un efecto positivo de la estrategia de "bien conectado", mientras que la estrategia de "intermediario" tiene un efecto negativo. Asimismo, se observa que las organizaciones de apoyo, la mayoría públicas, cumplen un rol crítico en la estructura de la red. En conjunto, estos resultados muestran la relevancia de la colaboración, así como los trade-offs que enfrentan los agentes intermediarios, resaltando la importancia de las organizaciones públicas en fomentar los flujos de conocimiento entre las empresas ocupando el costo de la intermediación.

Palabras clave: sector forestal, ecoturismo, sistema local de innovación, TIC avanzada, análisis de redes.

Códigos JEL: O14, O33, L14

(*) Carlos Bianchi, Institute of Economics, School of Economics and Administrative Sciences, University of the Republic, Uruguay. College of Business and Economics, University of Johannesburg, South Africa. Email: carlos.bianchi@fcea.edu.uy

(**) Pablo Galaso, Institute of Economics, School of Economics and Administrative Sciences, University of the Republic, Uruguay. Email: pablo.galaso@fcea.edu.uy

(***) Sofía Maio, Institute of Economics, School of Economics and Administrative Sciences, University of the Republic, Uruguay. Email: sofia.maio@fcea.edu.uy

(****) Sergio Palomeque, Management Department, School of Economics and Administrative Sciences, University of the Republic, Uruguay. Email: sergio.palomeque@fcea.edu.uy

Abstract

We analyse advanced ICTs acquisition in the territorial innovation system of the forestry and ecotourism industry in Uruguay, considering both firms and support organizations related to these sectors. Using social network analysis, we identify that firms follow different strategies of collaboration which generate distinct collective outcomes and imply varing individual costs and require diverse firms' capabilities. We capture two different firms' collaborative strategies by means of centrality indexes: intermediary (betweenness centrality) and well-connected (eigenvector centrality). While the latter captures a highly connected position in the network but without the costs of intermediating between third parties, the former does capture an intermediary role, which implies a central position in the network, but may entail costs for the holder. We estimate the effects of these collaboration strategies on the firms' probability to adopt advanced ICTs. Our results show a positive effect of the well-connected collaboration strategy on the adoption of advanced ICTs while intermediary strategy has a negative effect on the probability to adopt advanced ICT. At the same time, a critical role of support organisations, mainly public, in the structure of the network can be observed. Taken together, these results show the relevance of collaboration as well as the trade-offs faced by intermediaries, highlighting the importance of public organisations in fostering knowledge flows between firms.

Keywords: forestry, ecotourism, local innovation system, advanced ICTs, network analysis.

JEL Classification: O14, O33, L14

1. Introduction

In recent decades, ICT expansion has dramatically increasing in successive and overlapping waves. In this context, the expansion of "basic ICTs", as internet use and access, information management tools, etc., have altered the firms functioning worldwide. Currently, advanced ICTs are once again transforming the way firms produce and commercialise. Therefore, access to this type of technologies represents a key aspect for the development of product, process and organisational innovations, which in turn are critical for the competitive capacity of firms (Ciarli et al., 2021; UNCTAD, 2024).

In particular, Traditional activities based on natural resources exploitation are facing transition pressures towards digitalization and greening production systems worldwide (Lema and Rabelotti, 2023). This is a complex process involving global and national developmental goals and technological and economic dynamics under high uncertain trends. Diffusion waves of digital technologies have changing production activities at global level creating new challenges associated to potential windows of opportunity and new competitive pressures for laggard territories and firms (Tahvanainen et al., 2024).

The literature on innovation and development has widely corroborated that the probability to find and exploit windows of opportunity in the expansion phase of a technological paradigm critically depend on the innovation capabilities accumulated in territories and firms (Figueiredo and Cohen, 2019; Andreoni et al., 2021; Castillo and Vonortas, 2024).

In this perspective, innovation capabilities are a systemic attribute, associated to the collective innovation dynamics in the territory, where the collaboration linkages are critical for the generation and access to new knowledge (Henttonen and Lehtimäki, 2017; Aboal et al., 2018; Galaso and Rodríguez Miranda, 2021; Bianchi et al., 2023a). An extensive stream of research on firms' innovation has shown the relevance of interactive collaboration to access, adapt and use knowledge (Laursen and Salter, 2006; Johansson and Lööf, 2014). However, previous literature has also emphasised that collaboration requires resources and can imply costs according to different strategies followed by the agents. A firms' strategy aiming to embrace all possible collaboration linkages may present higher transaction costs and potential redundant or not exploitable knowledge (Bello-Pintado et al., 2022; Howells and Thomas, 2022).

In this regard, the role of intermediary agents, at different systemic levels – local, sectoral and national – and in different development contexts, has been widely analysed. This literature has given special attention to the organizations –public or private– specifically created and oriented to connect and intermediate between system agents, facilitating knowledge sharing and lowering interaction costs (Kauffeld-Monz and Fritsch, 2010). In particular, in immature innovation systems, intermediary agents play a critical role fulfilling the lacks of interaction between agents, that affects the functionality of innovation system (Intarakumnerd and Chaoroenporn, 2013; Klerkx et al, 2015; Galaso and Rodríguez Miranda, 2021). Nevertheless, in spite of the relevance of organizations specifically oriented to act as intermediaries, the functioning of the system leads to different actors taking intermediary positions and roles, beyond their specific mandate.

In this sense, the identification of these roles is not straightforward and the analysis of the interaction networks offers a valuable tool (Caloffi et al., 2015).

The literature on social network analysis (SNA), has emphasized the relevance of studying the structure of networks in order to understand innovation processes (e.g. Giuliani and Bell, 2005; Phelps et al., 2012). From this perspective, collaboration networks connecting firms and organisations are a way to approach territorial innovation systems, as they represent the dynamics of interaction and knowledge flows (Broekel et al., 2021). The position actors occupy in these networks reflects their collaborative strategies and influences their innovation processes, given that such positions may involve both benefits and costs.

For example, agents holding a central position in a collaboration network will have better access to knowledge fluxes favouring their knowledge accumulation. However, collaboration is not free of tensions, within the organizations and between competitors or partners (Koukouvinou et al., 2023). Playing a central role in collaboration networks involves costs and require firms to devote resources and capabilities (Klerkx and Aarts, 2013; Bianchi et al., 2023a). A trade off then arises between the advantages of holding a central position in the network and the costs of maintain links and intermediating between disconnected parts of the network (Operti and Kuar, 2023; Bianchi et al., 2023b and 2023c).

In this article, we aim to contribute to the literature on territorial innovation systems by analysing the trade-offs associated with certain network strategies and positions, studying both the potential benefits and the inherent costs of occupying these roles. In particular, we identify and study two collaboration strategies according to the positions that firms hold in networks (Burt 1992; Zaheer and Bell 2005): intermediary, referring to agents that bridge otherwise disconnected parts of the network, and well-connected, referring to agents that are linked to other highly central or influential nodes. Our aim is to explore what it means for a firm to follow such strategy —not only in terms of its own innovation capacity, but also regarding its contribution to the collective dynamics of the territorial innovation system.

While prior research has documented the effects of network position on firm performance, few studies have approached this issue from a trade-off perspective, considering how individual advantages may come with costs for either the firm or the system as a whole. We seek to address this gap by characterizing two distinct collaboration strategies, assessing their implications at both the firm and system levels, and providing empirical evidence on how these positions affect the adoption of information and communication technologies (ICTs).

To achieve the objective, we conduct an empirical study focused on forestry and ecotourism firms within the territory of the “South-north corridor” in Uruguay. The agglomeration of forestry and ecotourism firms, training and research centres, and support organizations, incipiently collaborating to production and innovation projects, shapes the territorial innovation system.

Drawing on a unique data set with information of a specific survey applied to firms and support organizations, we reconstruct and analyse the collaboration network among actors within this territorial innovation system, which constitutes the focus of our study. Based on this network, we pose the following research questions:

RQ1: What is the structure of the collaborative network in the South-north corridor?

RQ2: Which firms' collaboration strategies can be identified in the network?

RQ3: Does the firms' collaborative strategy affects the firms' adoption of advanced ICTs?

We draw on two widely recognized network centrality indicators which allow us to capture and measure the two collaboration strategies under study: betweenness centrality and eigenvector centrality. The first indicator captures collaborative strategies of intermediation, linking actors who are isolated from each other. The second one identifies actors who follow a collaborative strategy aimed at being well connected. By doing so, we identify two different strategies filling critical functions in knowledge sharing within the network (Watkins et al., 2015; Feser, 2023).

Based on these indicators, we follow a two-stage analysis strategy. First, to answer the first two research questions, we present a descriptive analysis of the collaborative network. In addition, to estimate the effect of collaboration and network positioning on the adoption of advanced ICTs, we incorporate network indicators as an explanatory variable in regression models with different specifications.

Our results show that local collaboration networks in the corridor is highly cohesive. However, collaborations are mostly defined around the sectoral hubs – forestry and ecotourism - with a relevant role played by support organizations. We identified differentiated effects of the firms' collaborative strategies on the adoption of advanced ICTs. Holding an intermediary position negatively affects digitalization, while being well-connected to central nodes positively affects ICTs adoption.

2. Literature review

2.1 Digital transition and firms' innovation

Digitalization have emerged as a megatrend, affecting production and consumption dynamics worldwide. In this context, several efforts to understand the potential effects of digitalization in developing countries have been made and potential windows of opportunity and critical effects have been discussed (e.g. MISTRA, 2021; CEPAL, 2021; UNCTAD, 2024).

ICT adoption affects the innovation process both within the firm and between firms and other agents (Ciarli et al., 2021). The nature of ICT may change the firms' routines, its skill requirements and the external collaborative linkages to innovate. Within a broad and diverse discussion agenda that encompasses the study of effects on employment and income distribution, the possible widening of gaps between different people and organisations, one strand of literature has analysed the potential effects of ICT adoption on firms' innovation and performance (e.g. Gaglio et al., 2022; Audretsch and Belitski, 2024).

In this regard, previous studies from developing countries generally show a positive and significant effect of basic ICT adoption, mainly associated with internet access, use of smart devices and communication networks, on the performance of firms acting in traditional manufacturing or agricultural production sectors (Chegue et al., 2020; MISTRA, 2021; Gaglio et al., 2022; Castillo and Vonortas, 2023).

Use of social networks and internet access facilitate the exchange of knowledge between firms, and between firms and customers or suppliers. These interactions multiply information that fosters product development and process improvements. In developed countries, with highly connected collaboration networks, as basic ICTs are already widely developed throughout society and economy, this factor would not seem to be as relevant today. However, in developing countries, where innovation systems are immature or incomplete (Rapini et al., 2009), access to the internet can critically expand communication capacity. Through the internet and social networks, firms can contact their customers, understand their needs, study the target audience and analyse competing firms in order to generate an innovative product or process for them and stand out in the market. In this way, the adoption of basic ICTs foster firms' growth with low investment requirements and is a stepping stone for foster adoption of advanced ICTs. However, the effects of basic ICTs adoption are mainly restricted to create absorptive capacities and innovation outcomes, mostly process innovation, with uneven effects on firm's performance, according to the firm's innovative capabilities (Cuevas-Vargas et al., 2022; Gaglio et al., 2022; Castillo and Vonortas, 2023).

This literature offers a rich background on different aspects of firms' ICT adoption in developing countries and its effects. However, these works are mostly focused on basic ICTs, without distinguishing most advanced technologies related to the current digitalization wave. Following recent works on the topic (OECD, 2015; ECLAC; 2015; Lorenz and Kraemer-Mbula, 2022), in this paper we distinguish between basic ICTs; which refer to the use of office computer, internet and social network access for business activities; and advanced ICTs, which refer to those digital technologies of the fourth industrial revolution, that have the potential to change productive process.

In particular, advanced ICTs have acquired an increasingly important role in the production system in forestry industries. For example, in forest management, advanced ICTs, mostly based on internet of things (IoT) and drones, allow collecting large amount of data that, in turn, make it possible to coordinate heterogeneous stake holders (Pleger and Schiering, 2023). These changes have drastically modified the wood value chain management (Müller et al., 2019). Moreover, technologies of global positioning system and geographic information systems are extensively used for sustainable management and risks prevention (Moguillansky, 2005). On the other hand, the literature highlights that the adoption of advanced ICTs enhances the development and adoption of innovations and practices for environmental sustainability. This, in turn, favours the integration of the forestry sector with other economic activities (Damaševičius et al., 2024).

Digitalization is also a crucial tool for ecotourism development. The experiences in this sector emphasise the relevance of local community and territorial tradition in the innovation and ICT adoption process (Zainol et al., 2023). Moreover, these authors emphasise the relevance of basic ICTs, in particular the use of digital communication and internet based commercialization tools. These technologies contribute to create demand for ecotourism, facilitating information access for tourists. Advanced ICTs, in particular related to big databases store and processing, appear also as key technologies but operated by global players and mass tourist destination, rather than by local firms related to eco-tourism entrepreneurship (Zegiri et al., 2020). However, previous studies also show the potential benefits of advanced ICTs in ecotourism, highlighting the importance of technologies as IoT and data store in connecting local entrepreneurs with a global demand, and, also, fostering the promotion of sustainable practices (Zhang et al., 2024). In this sense, ICT adoption in ecotourism activities can contribute to process a twin – digital and green- sectoral transition (Rasyidah et al., 2023; Li and Zhang, 2025).

In developing countries, advanced ICTs may represent opportunities for productivity gains and innovative performance, but it also may imply risks, especially regarding job substitution (Lorenz and Kraemer-Mbula, 2022). In particular, works on innovation in forestry industry have emphasised the relevance of a systemic approach, focusing on the articulation between forestry industry agents, agents from related activity sectors and support organizations (Kubeczko et al., 2006).

These background show the relevance of a systemic approach, which basic building blocks are interactions between agents, which share complementary and non-redundant knowledge. In the next section we elaborate on the relevance of the collaborative strategies of agents and the potential effects on their innovative performance.

2.2 Collaboration strategies, network roles and trade-offs for innovation

Actors within a territorial innovation system—including firms, research centres, government agencies, and others—interact and collaborate through networks. The literature on social network analysis, as applied to contexts such as clusters, industrial districts, innovation systems, and business networks, has consistently emphasized the critical role of these collaborative networks in shaping territorial innovation processes (Broekel et al., 2021).

From a collective perspective, the structure of these networks can either facilitate or hinder innovation by enabling the generation of new knowledge, accelerating the exchange and refinement of ideas, and promoting the incorporation of external knowledge into the territory (Fleming et al., 2007; Galaso and Kovarik, 2021). Crucially, the structure of the network is determined jointly by all participating actors (i.e. by whom each actor collaborates with) and, at the same time, collectively belongs to them. For this reason, such networks can be conceptualized as a form of collective capital, embedded in the territory where the innovation system is located (Galaso, 2018).

However, this collective capital does not affect all firms in the network equally (Giuliani and Bell, 2005). The literature has shown that the effects of the network on individual actors vary depending on their position within it. For instance, firms occupying more central positions are more likely to access the knowledge circulating through the network—more directly, more quickly, and more reliably—than peripheral actors (Powell et al., 1996; Ahuja, 2000). Therefore, at the individual level, understanding a firm's innovative performance requires analysing its position in the network. Prior research has linked this position to key strategic business characteristics such as firm size, export orientation, innovation adoption, and territorial embeddedness of activities (Galaso and Rodríguez Miranda, 2022).

Accordingly, a firm’s position in the network of a territorial innovation system can be interpreted as reflecting its collaborative strategy, insofar as:

(1) it emerges both from decisions made by the firm (e.g., whom to collaborate with or not) and from external factors (e.g., the collaboration choices of its partners and their partners in turn), and
(2) it affects not only the firm’s own outcomes (by enabling or constraining innovation), but also those of other actors (since it contributes to the overall structure of the network).

Nonetheless, this strategy should not necessarily be understood as the result of a deliberate plan by the firm to occupy a specific network position. Rather, we argue that it is better conceptualized as the decentralized outcome of multiple collaboration choices made by actors across the territorial innovation system, resulting in a network structure in which each firm ends up occupying a particular position.

In what follows, we analyse two distinct types of collaborative strategies based on firms’ positions within the network. Specifically, we use two different network centrality measures. While social network analysis literature has long examined centrality as an indicator of node prominence or relative importance, it has also shown that centrality can be conceptualized and measured in various ways, each capturing a different dimension of prominence (Wasserman and Faust, 1994). We focus on two widely used centrality metrics that correspond to two distinct collaborative strategies: intermediary (measured by betweenness centrality) and well-connected (measured by eigenvector centrality). For each strategy, we describe what it implies in terms of network position and its effects on innovation at both the individual and collective levels. Based on these arguments, summarized in Table 1, we formulate our research hypotheses.

Table 1. Collaboration strategies and innovation

Network indicator	Intermediary Betweenness centrality	Well-connected Eigenvector centrality
Position and role in the network	- Located in the shortest paths connecting other nodes - Contribute to overall network cohesion	- Connected to most central agents - Contribute to the formation of a core-periphery structure
Implications for innovation	- Easy access to non-redundant knowledge - Costs of intermediating between disconnected actors	- Easy access to knowledge circulating within the network - Without bearing the costs of intermediation
Hypothesis	Negatively associated with advanced ICT adoption	Positively associated with advanced ICT adoption

First, the intermediary strategy is characterized by high levels of betweenness centrality. This means that actors adopting this strategy tend to occupy positions along the shortest paths (geodesic) that connect different nodes in the network. These broker positions in the network imply a great ability to control and facilitate the flow of information and resources within a network. In other words, agents with high betweenness centrality play strategic roles that connect separate communities or groups of actors in the network that would otherwise be isolated from each other. Intermediary actors are not necessarily the most influential or powerful in the network, but they are often the ones who contribute the most to the global cohesion of the network, as eliminating these nodes makes it more likely for the network to fragment into disconnected components. Therefore, nodes with high betweenness centrality are the ones that facilitate collaboration between separated groups, playing a critical role in building collective knowledge.

This contribution to global cohesion and knowledge circulation may have different effects at the individual level for the actors acting as intermediaries. On one hand, it can provide them with the opportunity to access non-redundant information —precisely because it originates from unconnected sources—, which, in turn, can be highly valuable for innovation processes and technology adoption (Ahuja, 2000). However, on the other hand, it involves high costs in terms of intermediation. Keeping nodes that are disconnected from each other connected requires the ability to interact with diverse actors, which often demands significant time and effort (Giuliani 2007; Laursen and Salter, 2014). This may impact negatively on innovation performance and technology adoption processes conducted by intermediary firms (Gao and Zhu, 2022; Bianchi et al., 2023b). In fact, previous studies have documented a negative relationship between betweenness centrality and innovation generation (Whittington et al., 2009; Galaso and Kovarik, 2021). In particular, in innovation networks from developing countries, those firms playing an intermediary role may face a severe resource restriction.

Based on these arguments, we propose our first hypothesis as follows:

H1. The firm's betweenness centrality is negatively associated with its adoption of advanced ICTs.

The second strategy—the well-connected strategy—is defined by eigenvector centrality. This indicator measures the prominence of a node based on the importance of its neighbours. In other words, actors with high eigenvector centrality are those who are connected to the best-connected actors in the network (Borgatti et al., 2013; Jackson, 2008). Therefore, this indicator reflects structural influence, which can also be understood in terms of prestige and power. Nodes with high eigenvector centrality are usually part of the core of the network, meaning the group of the most connected and influential nodes in the network (Borgatti and Everett, 2000).

At the collective level, highly central nodes facilitate the rapid diffusion of knowledge, as core-periphery structures are highly efficient in connecting most nodes in just a few steps. However, these hierarchical structures also tend to reproduce dominant flows and ideas, which may lead to the homogenization of knowledge and, consequently, limit the exploration of novel ideas. By this way, this structure determines the access channels to external technology, potentially defined technological paths in territorial and sectoral innovation systems. At the individual level, nodes with high eigenvector centrality may benefit from their central position by gaining access to the knowledge circulating within the network without bearing the costs of intermediation. This is because they do not necessarily act as bridges between otherwise disconnected parts of the network. Therefore, as shown empirically by several previous studies (e.g. Aktamov and Zhao, 2014; Zhang et al., 2025), eigenvector centrality can facilitate the development of innovations and the adoption of new technologies.

Based on the above arguments, we present our second hypothesis as follows:

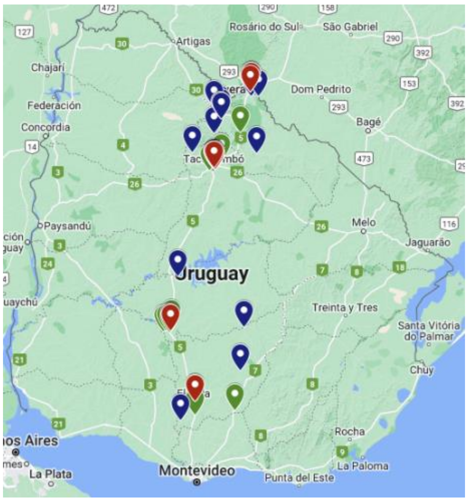
H2. The firm's eigenvector centrality is positively associated with its adoption of advanced ICTs.

3. Context of the study

We analyse the incidence of the collaboration networks in the ICT adoption of forestry and ecotourism firms within the territory of the “South-north corridor” in Uruguay. This corridor corresponds to the Uruguay's National Route 5 (Figure 1), which connects Montevideo, the capital city of Uruguay, with Rivera, a city located on the Brazilian border, passing through several intermediate localities including Florida, Durazno, and Tacuarembó. The corridor extends across a large and diverse territory. Nevertheless, it shares key characteristics, including a common focus on forestry-related production (Figure 2) and a recurring pattern of collaboration among firms, research organizations, and public institutions, which reflects the dynamics of a territorial innovation system. Furthermore, the Route 5 serves as a backbone that that fosters territorial cohesion across the cities of the corridor (Morales Olmos, 2021; Bortagaray et al., 2022).

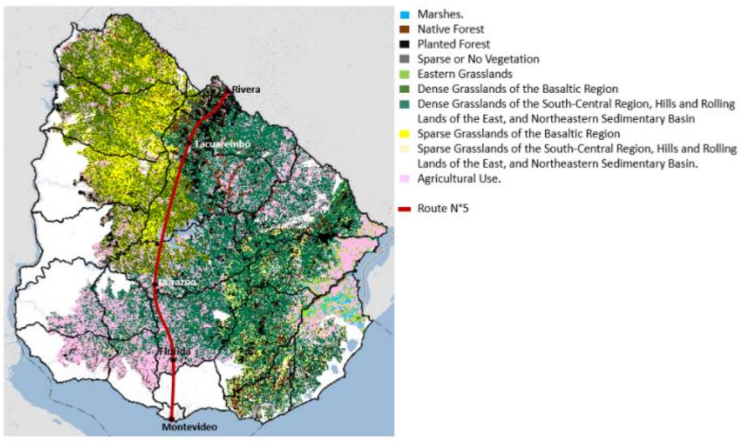
This territory has suffered critical changes in the last two decades. Since the Forestry Law, introducing subsidies and tax exonerations to promote forestry industry, was passed in 1988, the land uses dramatically changed and artificial forest expands while different manufacturing and services activities around the wood-forest complex unevenly arise. More recently, this territory received some of the biggest private investment in the recent Uruguayan history, with the localization of big factories of multinational companies of pulp and paper. The rise and expansion of activities related to the forest-wood have triggered a number of initiatives aiming to strength the local network of this industry, considering manufacturing and services productive linkages, as well as, specialized research and higher education supply (Morales-Olmos and Siry, 2009; Morales-Olmos, 2021). Meanwhile, during these decades national and local governments, the autonomous public university and other technological institutes expanded their activities related to research, innovation and technical trainee along the countryside. As part of this process new research and higher education campus were created in different cities along the corridor (Stuhldreher, 2020). However, as this author points out, the evolution of the forestry system and the prospects for sustainable development in this territory face major challenges. Among them, great challenges emerge from the diffusion of digital technologies that can transform the form of production and employment.

Figure 1. Uruguay map and localization of firms and organizations surveyed.



Note: green markers represent forestry companies, blue ones represent ecotourism companies, and red ones represent support organizations.
Source: Own elaboration using Google Maps (2024), based on addresses collected in a 2021 survey.

Figure 2. Uruguay land use map (2024)



Source: Own elaboration (2025), based on land use data from the Ministry of Livestock, Agriculture and Fisheries (MGAP), Directorate General of Natural Resources (DGRN), accessed via the DGRN online viewer (https://dgrn.mgap.gub.uy/js/visores/dgrn/).

Moreover, in spite of the economic growth of the forestry related activities, the development of innovative systemic dynamics in the territory is still incipient and its drivers are not clearly identified. A previous work has stressed the relevance of multinational companies building collaborative networks in the local forestry and pulp industry (Aboal et al., 2018). However, the global business strategies and the innovation dynamics in this industry also show critical bottle necks in the medium run (Tahvanainen et al., 2024). In addition, the articulation of the forestry-wood industry with other activities, in particular, with environmentally friendly activities associated with the use of natural resources, is still weak (Kefeli et al., 2023).

Likewise, a fundamental challenge for this territory is the diversification of economic activities, in a complementary way with the development of the forestry sector, and, at the same time, to promote socially and environmentally sustainable solutions. In this sense, one of the strategies that have gained strength in the territory is the development of ecotourism activities (Antón and Sans, 2007). Tourism accounts for a significant share of GDP in Uruguay, which is the Latin American country with the highest amount of inbound tourism per capita (Brida et al., 2020).

Previous studies in developed and developing countries have analysed the potential complementarity between forestry activities and ecotourism as a diversification strategy (Rodríguez-Piñeros and Mayett-Moreno, 2015; Connell et al., 2017). As these works have shown, diversification strategies in forestry areas are not free from tensions and potential conflicts, being critical the role of local agents. In this sense, although this type of activity is relatively unexplored in Uruguay, there are relevant experiences in the territory, linked to the promotion of social actors and support organisations (Bazzani and Canduro, 2019).

Innovation activities and technological acquisition are critical drivers for both, the development of the forestry industry and its articulation with other activities along the territory. In particular, due the digitalization trends, ICT acquisition and adoption in the production activities, appear as a necessary condition for the sectoral and territorial development. However, as an extensive research background has documented, traditional activities, as forestry industry, involve heterogeneous agents with dissimilar capabilities to accessing technological solutions. Knowing the available supply and acquiring and adopting advanced ICTs requires capabilities of agents. Such capacities are building by use and interaction, giving rise to firms specific resources but also to collective systemic capabilities.

4. Methodology

In order to answer the research questions, we followed a two-step strategy. First, we applied a descriptive analysis of the collaboration network to study the characteristics of the network structure and to identify the collaboration strategies followed by the firms (RQ1 and RQ2). In a second step, we employ econometric techniques to answer RQ3 and test our two hypotheses.

4.1 Data

We conducted a unique survey to collect information on collaborative links to innovate and the uses and demands of ICTs by 55 firms belonging to the forest-wood industry and ecotourism, and 27 support organisations, acting in the South-north corridor (Bortagaray et al., 2022).

The selection of firms for the survey was made according to the economic activity records of the National Statistical Institute of Uruguay (2019). The initial sample of firms was completed from administrative records and specialised works. For the forestry sector, information published in Uruguay XXI (2021) and Morales Olmos (2021) was used. The sample of ecotourism firms was completed with information published by the Ministry of Tourism on the following topics: rural tourism, wineries, adventure tourism and tourist accommodation.[1] Recently developed ecotourism clusters in the corridor territory were also included.

These sources of information were used to identify an initial sample in each sector. In addition, for both sectors, the 'snowball' method was applied, which is carried out by consulting firms already identified by other relevant firms or institutions in the territory, with whom they have maintained links to innovate (Bortagaray et al., 2022). The survey collected information focused on three dimensions: innovation activities carried out by firms; adoption of basic and advanced ICTs; and collaboration and linkages between actors operating in the territory. Questions related to innovation activities were based on the Oslo Manual (2005). The questions on ICT adoption were developed on based of international references (OECD, 2015; ECLAC; 2015), which were adapted and tested for application in firms, mainly SMEs, acting in the Uruguayan context. The survey collected information on the firms' acquisition of ICTs considering both, those solutions classified as basic ICT –use of informatics devices for business, internet access and own of web site or social networks – or advanced ICT– cloud computing, internet of things (IoT), use of robots, and ICT security tools. Moreover, all respondents, firms and support organisations, were asked which other firms and organisations they collaborated with for different innovation activities.

The South-north corridor covers four departments (provinces), from the middle south to the north of Uruguay (Table 2). Most of the firms surveyed (76%) are located in the department capital cities, mostly in the north side of the corridor, close to the Brazilian frontier. 55% for the firms are related to the forestry sector, including forestry and wood firms as well as firms acting in related services, as transport and logistic. The rest of the firms offer ecotourism services. Surveyed firms are mostly SMEs (96%) with relative long experience in business.

[1] https://www.gub.uy/ministerio-turismo/datos-y-estadisticas/datos-abiertos)

Table 2. Firms and organizations surveyed.

Department (Province)	Firms	Support Organizations
Florida	5	1
Durazno	9	1
Tacuarembó	23	19
Rivera	18	6
Total	**55**	**27**

Surveys were also conducted to 27 support organizations (research centres, universities, local development agencies, and civil associations). 24 of these organisations are dedicated to research and/or higher education and the remaining 3 are associated with productive and business promotion. This allows the collaboration network to be completed by incorporating not only firms, but also organizations that engage with them and shape knowledge creation and innovation diffusion processes.

4.2 Collaboration network

Using social network methods, we analyse the territorial innovation system focusing on the forestry industry and potential diversification towards ecotourism. In doing so, we build the collaboration network composed by firms and organizations acting in forestry and ecotourism in the territory of the corridor. The nodes of the networks are the firms and organisations surveyed or mentioned by the surveyed agents while the links are defined when an agent mentions other agent as partner in innovation or productive activities.

Subsequent to the construction of this network, we calculate indicators for the two collaboration strategies under consideration: *betweenness centrality* and *eigenvector centrality*. First, *betweenness centrality* aims to capture the *intermediary* role by measuring the extent to which a node lies on the shortest paths connecting other nodes of the network. Second, *eigenvector centrality* captures the *well-connected* strategy following a reciprocal process in which the centrality of each actor is proportional to the sum of the centralities of the actors to which it is connected. These two indicators are widely used in the SNA literature to study the knowledge flows in collaboration networks. Formal definitions of these indicators are available in standard network texts (e.g. Jackson, 2008; Borgatti et al., 2013).

4.3 Econometric strategy

Aiming to test the effects of the collaboration strategies on the adoption of advanced ICTs, we estimate a set of econometric models using different regressions specifications for dichotomist dependent variable. First, we estimate the effects of *betweenness* and *eigenvector centralities* on the probability to adopt advanced ICTs considering the adoption of: cloud computing, IoT, robots and ICT security. Second, we estimate the same model but using a more restrictive definition of advanced ICTs that do not include cloud computing. In spite of the relevance of cloud computing in advanced ICTs, we omit this dimension in the second dependent variable considered since the information collected shows that several firms use basic ICT in the cloud, rather than reporting cloud computing in central functions of the firm.

Table 3. Variables for econometric estimations

Dependent variables	
Advanced ICT total	Dummy variable that takes value 1 if the firm adopted cloud computing, IoT, robots or ICT security, 0 otherwise
Advanced ICT selected	Dummy variable that takes value 1 if the firm adopted IoT, robots or ICT security, 0 otherwise
Explicative variables	
Betweenness Centrality	Numeric variable that represents how much a node is part of the shortest paths connecting other nodes. The higher its value, the more intermediary the node is.
Eigen Centrality	Numeric variable that represents how strongly a node is connected to others nodes with high centrality. The higher its value, the node has better connections.
Control variables	
Innovation activities	Count variable that counts the number of innovation activities conducted by the firm considering: R&D, Acquisition of capital goods, Process/organisational improvements, Technology transfers/Consultancy, Quality Certifications and Training.
Area of activity	Variable that represents the area of activity of the firm
Workforce education	Numeric variable that represents the ratio between the number of employees with complete or incomplete tertiary education and employees with lower levels of education.
Obstacles to cooperate	Dummy variable that takes value 1 if the firm perceives at least 1 obstacle to cooperating with other firms or organizations.

5. Results

5.1 Descriptive analysis: ICT adoption and innovation behaviour of the firms

The information collected on the firms' use of ICT solutions reveals that almost all firms have incorporated basic ICTs –web site, internet high-speed connections, etc.– and, unexpectedly, a relative high share of firms have incorporated advanced ICTs solutions

(Table 4). Most of firms acquired these solutions within the local market, except of the solutions associated with the ICT Security which were mostly purchased abroad.

Almost all firms surveyed (98%) use some type of basic ICTs, with a high adoption rate both in forestry and ecotourism firms. As expected, the adoption of advanced ICTs is quite unequal between sectors (Table 4). While 60% of the firms in the whole sample adopted some type of advanced ICTs, these firms correspond to 80% of the forestry firms and 36% of the ecotourism firms. These figures, which reflect the different productive process in these sectors, are mainly due to the use of IoT and ICT security, and, to a lesser extent, due to the use of robots.

The most widely used type of IoT tools among forestry firms are sensors for products and vehicle tracking, followed by sensors and cards for monitoring and automation of production processes, and finally smart meters/lighting/thermostats. Regarding the use of robots, there are those that perform industrial tasks (on the production line) and others that are called service robots (management support). The latter are the most widely used, with 16% coverage, while industrial robots account for only 7%. Finally, the ICT security tools used by the firms in the corridor include various aspects such as strong password authentication, biometric identification, data encryption, access controls, use of virtual private networks and regular ICT risk assessment and security testing.

Table 4. Advanced ICT acquired by firms in the Corridor

Advanced ICT	Forestry-wood (and associated services)	Eco-tourism	Total
Cloud Computing	26,67%	28,00%	27,27%
Internet of Things	60,00%	8,00%	36,36%
Robots	23,33%	12,00%	18,18%
IT Security	46,67%	12,00%	30,91%

With regard to the firms' innovation strategies, 93% of the firms surveyed reported having carried out some innovation activities. In accordance with previous works on innovation in the Uruguayan economy (Machado and Bianchi, 2024), the main innovation activities carried out refer to the external acquisition of knowledge, either incorporated in capital goods, trainee activities or in the form of consultancy and technology transfer, while fewer firms report having carried out R&D (Table 5).

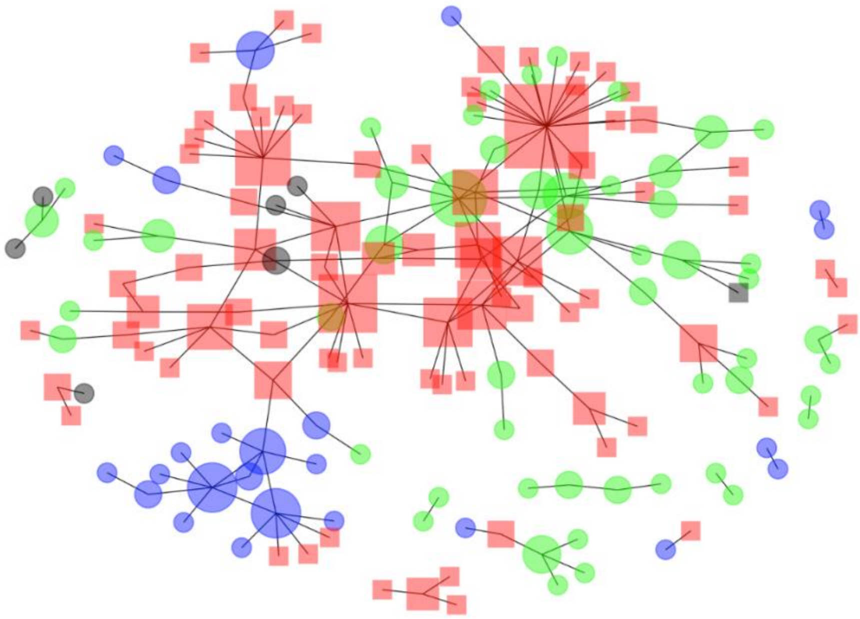
Table 5. Innovation activities conducted by firms in the Corridor

Innovation activities	Forestry-wood	Eco-tourism	Total
R&D	43,33%	28,00%	36,36%
Capital Goods for innovation	80,00%	44,00%	63,64%
Process/organisational improvements	76,67%	64,00%	70,91%
Technology transfers/Consultancy	46,67%	24,00%	36,36%
Quality Certifications	30,00%	24,00%	27,27%
Training	73,33%	56,00%	65,45%

5.2. Descriptive analysis: network structure

The collaboration network composed by the firms and support organization acting in the corridor is well-cohesive (Figure 3). Graphical analysis allows to observe a giant component that brings together most of the nodes, while only a few agents remain in small components.

Figure 3: Corridor network.



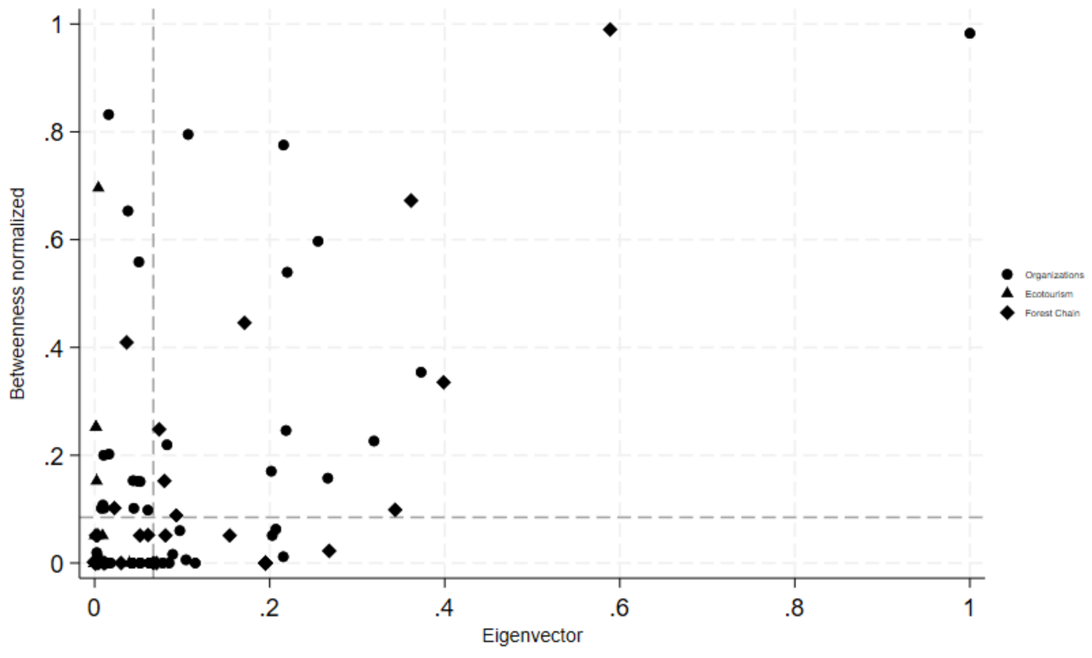
Note: Firms acting in forestry and related activities are in green in the graph, ecotourism firms are in blue, other activities in grey and organizations in red. Circular nodes represent firms, while square nodes represent support organizations.

Furthermore, the network presents a typically scale free structure: most of the nodes have only one or two links, while a few hubs are highly connected. It implies that there is a preferential attachment mechanism whereby most nodes are linked into highly connected hubs. These hubs are mainly conformed according to activity sectors: in the central part of the graph, there is a group of hubs (many of them support organizations) that brings together forestry-wood companies; on the other hand, in the lower-left part of the graph, another group of hubs (less numerous and led by private firms) connects firms in the ecotourism sector.

This network configuration suggests a weak articulation between forestry and ecotourism sectors. In addition, graphical analysis suggests that support organisations also form a specific hub, but there are organizations that seem to play a sort of broker role between firms' sectoral hubs. In this regard, our results are in line with previous works – both from Uruguay and abroad – that have stressed the relevance of support organization as broker agents and enhancer innovation in collaborative innovation (Watkins et al., 2015; Galaso and Rodríguez Miranda 2021; Galaso et al., 2024).

Figure 4 represents the relationship between the two collaboration strategies considered. The graph allows observing some general patterns in collaborative strategies according the type of agents. In this sense, ecotourism firms present low levels in both indicators, while support organization show high values of intermediary roles (Betweenness centrality). Meanwhile, forest firms show variegated levels of both intermediary and well-connected (Eigenvector centrality) strategies.

Figure 4. Collaboration strategies: plot representation



Moreover, graphical analysis of the collaboration strategies, seems to corroborate previous interpretations on the role played by key agents in knowledge network in Uruguay. The forestry firms that present higher values of both collaboration strategies are multinational companies on wood production and processing. In this sense, Figure 4, seems to corroborate previous research of Aboal et a (2018), who found evidence of the role of multinational forestry companies in Uruguay, which, through different cooperation strategies, contribute to strengthening the sectoral innovation system. In the same sense, the descriptive analysis seems to corroborate the findings of Galaso and

Rodriguez Miranda (2022) and Galaso et al (2024), who highlight the importance of support organisations in local production systems in Uruguay and other Latin American countries. In particular, the intermediary role assumed by these agents, mostly public, or collective associations of private agents, suggests the importance of strengthening their role, in order to contribute to the strengthening of collective capacities.

5.3. Econometric results

Econometric results corroborate our hypotheses, showing a positive effect of *well-connected* collaboration strategies, while those firms that follow an *intermediary* strategy shows negative effects on the probability to adopt advanced ICTs. These results are confirmed using both, the dependent variable including the total of advanced ICTs incorporated by the firms (Table 6) and using the restricted classification of advanced ICTs (Table 7).

Table 6. Probit models – Dependent variable: Advanced ICT - Total

	(1)	(2)	(3)	(4)	(5)
Innovation activities	0.383***	0.413***	0.337***	0.462***	0.461***
	(0.00181)	(0.00110)	(0.00820)	(0.000627)	(0.000559)
Area of activity	0.223	0.213	0.342	0.355	0.355
	(0.236)	(0.275)	(0.148)	(0.149)	(0.148)
Workforce education	3.771	3.941	4.510	6.443**	6.414**
	(0.143)	(0.143)	(0.117)	(0.0364)	(0.0348)
Betweenness Centrality		-0.000181		-0.00127*	-0.00126*
		(0.707)		(0.0528)	(0.0560)
Eigen Centrality			12.24**	15.50***	15.51***
			(0.0257)	(0.00738)	(0.00695)
Obstacles to cooperate					-0.0196
					(0.962)
Constant	-1.489**	-1.513**	-1.885***	-2.143***	-2.130***
	(0.0150)	(0.0113)	(0.00599)	(0.00316)	(0.00306)
Observations	55	55	55	55	55
Pseudo R2	0.2138	0.2158	0.2878	0.3320	0.3320
Log pseudolikelihood	-29.102798	-29.028406	-26.363781	-24.725699	-24.724618

Robust S.E. in parentheses
*** p<0.01, ** p<0.05, * p<0.1

In addition, econometric results confirm a clear positive relationship between innovation activities conducted by the firm and the adoption of advanced ICTs. Conversely, the firm's workforce educational level does not show significant effects, except when considering the ICT variable which includes cloud computing (Table 6).

Moreover, we run several robustness test that corroborate these results. Probit models using only the linked firms, both considering all advanced ICTs (Appendix - table A5) and selected advanced ICTs (Appendix - table A6). Additionally, we estimated the same models using linear regressions and obtained similar results (Appendix Table A1 to A4).

Table 7. Probit models – Dependent variable: Advanced ICT - Selected

	(1)	(2)	(3)	(4)	(5)
Innovation activities	0.358***	0.394***	0.308**	0.425***	0.424***
	(0.00237)	(0.00127)	(0.0106)	(0.000338)	(0.000300)
Area of activity	0.215	0.199	0.342	0.347	0.346
	(0.232)	(0.285)	(0.139)	(0.152)	(0.152)
Workforce education	0.209	0.175	0.169	0.113	0.134
	(0.393)	(0.480)	(0.641)	(0.796)	(0.782)
Betweenness Centrality		-0.000247		-0.00149**	-0.00148**
		(0.570)		(0.0389)	(0.0400)
Eigen Centrality			13.69**	17.11***	17.13***
			(0.0172)	(0.00509)	(0.00453)
Obstacles to cooperate					-0.0589
					(0.882)
Constant	-1.452**	-1.463**	-1.852***	-2.028***	-1.994***
	(0.0131)	(0.0115)	(0.00502)	(0.00288)	(0.00296)
Observations	55	55	55	55	55
Pseudo R2	0.1653	0.1677	0.2539	0.3147	0.3150
Log pseudolikelihood	-31.697752	-31.5417	-28.273605	-25.968711	-25.95844

Robust S.E. in parentheses
*** p<0.01, ** p<0.05, * p<0.1

6. Discussion and final considerations

The collaboration network between firms in the forestry and ecotourism sector and support institutions allow for an adequate approximation to the territorial innovation system in the South-north corridor of Uruguay.

This study highlights the critical role of collaboration networks in fostering advanced ICT adoption and innovation within the forestry-ecotourism sectors along the South-north corridor in Uruguay. The collaboration network structure indicates a cohesive system with dominant sectoral hubs, and a critical bridging role played by support organizations. This structure aligns with existing literature emphasizing the importance of network cohesion and sectoral clusters in regional innovation systems.

The identification of two collaboration strategies, notably between firms holding *intermediary* roles versus those *well-connected* to central nodes, is particularly insightful. Empirical findings confirm that firms with higher *eigenvector centrality*—those connected to influential, well-connected actors—are more likely to adopt advanced ICTs. This is in line with theoretical interpretations suggesting that being embedded within influential network cores enhances access to resources and information conducive to technological adoption and innovation. Conversely, firms acting as *intermediaries*—or brokers—exhibiting high *betweenness centrality*, tend to face higher costs and resource constraints, which negatively impact their ICT adoption. This finding underscores the complex trade-offs in innovative collaboration: intermediaries facilitate knowledge flow at the collective level but may be hindered by resource limitations at individual level.

Table 8 summarises the results observed in this regard, while highlighting the importance of recognising the different effects at the individual and collective level. This seems a fundamental aspect for the design of public policies aimed at aligning agents' objectives with national and territorial development goals.

Table 8. Collaboration strategies: individual vs collective outcomes

	Intermediary (Betweenness centrality)	**Well-connected** (Eigenvector centrality)
Collective outcomes (network)	Positive contribution	Positive contribution
Individual outcomes (firms)	Negative contribution	Positive contribution

These results must be considered within the specificities of the system analysed and the sectors of activity considered. In immature systems, it seems reasonable to expect that intermediation costs will be high, requiring building efforts. In line with this possible interpretation, as can be seen in the descriptive analysis of the network, support organizations appear to fulfil these roles.

Furthermore, the positive relationship between innovation activities and advanced ICT adoption emphasizes the intertwined nature of innovation processes and digital transformation. This aligns with the literature asserting that active engagement in innovation amplifies firms' capacity to leverage new technologies, vital for firms acting in traditional sectors in developing countries.

On another hand, the observed sectoral hubs within the network structure suggests limited cross-sectoral articulation between forestry and ecotourism, potentially constraining synergies for diversified and sustainable development. This seems to reveal that diversification strategies involving these sectors are still incipient, and reinforces the idea that the network reflects a system under construction. Addressing such fragmentation could unlock broader innovation capacities and green transition opportunities, especially as digital technologies can facilitate sustainable resource management and eco-tourism promotion.

On the other hand, beyond the system studied, this paper contributes to the literature on SNA and innovation, presenting results on the different types of centrality that can be observed in a network and how this may reflect firms' collaboration strategies. In this sense, the trade-off observed between the strategies of *well-connectedness* (high eigenvector centrality) and *intermediation* (high betweenness centrality) merits future research. In particular, it should be possible to compare how this effect varies according to the type of nodes that make up the network (e.g. people, firms, territories) and the geographical scope of the link (local, national, global.

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Appendix

Table A1. Linear regression models– Dependent variable: Advanced ICT - Total (Linked firms)

	(1)	(2)	(3)	(4)	(5)
Innovation activities	0.116***	0.0997*	0.0745	0.0990*	0.109**
	(0.000748)	(0.0548)	(0.171)	(0.0626)	(0.0493)
Area of activity	0.0633	0.0793	0.117	0.118	0.125
	(0.294)	(0.254)	(0.141)	(0.148)	(0.102)
Workforce education	0.0891	0.0547	0.0821	0.0501	0.0657
	(0.234)	(0.376)	(0.181)	(0.441)	(0.329)
Betweenness Centrality		-1.13e-05		-0.000290	-0.000281
		(0.946)		(0.153)	(0.177)
Eigen Centrality			0.987	1.842**	1.723*
			(0.100)	(0.0246)	(0.0511)
Obstacles to cooperate					-0.144
					(0.369)
Constant	0.0974	0.158	0.0956	0.0596	0.0839
	(0.609)	(0.538)	(0.708)	(0.815)	(0.745)
Observations	55	38	38	38	38
R-squared	0.197	0.141	0.193	0.242	0.264

Robust S.E. in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table A2. Linear regression models– Dependent variable: Advanced ICT - Selected (Linked firms)

	(1)	(2)	(3)	(4)	(5)
Innovation activities	0.127***	0.107*	0.0689	0.106**	0.115**
	(0.000502)	(0.0500)	(0.219)	(0.0263)	(0.0274)
Area of activity	0.0737	0.0844	0.137*	0.138*	0.145*
	(0.216)	(0.220)	(0.0923)	(0.0951)	(0.0656)
Workforce education	0.0303	0.0458	0.0875	0.0394	0.0530
	(0.519)	(0.452)	(0.132)	(0.483)	(0.351)
Betweenness Centrality		-4.75e-05		-0.000435**	-0.000428**
		(0.775)		(0.0141)	(0.0225)
Eigen Centrality			1.281*	2.564***	2.460***
			(0.0522)	(0.000946)	(0.00319)
Obstacles to cooperate					-0.126
					(0.423)
Constant	-0.00650	0.0831	-0.000325	-0.0544	-0.0333
	(0.971)	(0.741)	(0.999)	(0.804)	(0.882)
Observations	55	38	38	38	38
R-squared	0.209	0.139	0.219	0.321	0.336

Robust S.E. in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table A3. Linear regression models– Dependent variable: Advanced ICT – Total (All firms)

	(1)	(2)	(3)	(4)	(5)
Innovation activities	0.116***	0.118***	0.0980**	0.116***	0.116***
	(0.000748)	(0.00102)	(0.0107)	(0.00152)	(0.00173)
Area of activity	0.0633	0.0621	0.0877	0.0870	0.0870
	(0.294)	(0.343)	(0.226)	(0.238)	(0.243)
Workforce education	0.0891	0.0873	0.104	0.0803	0.0805
	(0.234)	(0.270)	(0.198)	(0.345)	(0.361)
Betweenness Centrality		-1.29e-05		-0.000279	-0.000279
		(0.930)		(0.166)	(0.172)
Eigen Centrality			0.849*	1.718**	1.717**
			(0.0909)	(0.0324)	(0.0384)
Obstacles to cooperate					-0.00115
					(0.993)
Constant	0.0974	0.0983	0.0591	0.0391	0.0397
	(0.609)	(0.615)	(0.767)	(0.846)	(0.851)
Observations	55	55	55	55	55
R-squared	0.197	0.197	0.223	0.253	0.253

Robust S.E. in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table A4. Linear regression models– Dependent variable: Advanced ICT – Selected (All firms)

	(1)	(2)	(3)	(4)	(5)
Innovation activities	0.127***	0.135***	0.104***	0.133***	0.133***
	(0.000502)	(0.000219)	(0.00992)	(7.38e-05)	(9.29e-05)
Area of activity	0.0737	0.0677	0.104	0.103	0.103
	(0.216)	(0.289)	(0.150)	(0.163)	(0.168)
Workforce education	0.0303	0.0210	0.0494	0.0111	0.0120
	(0.519)	(0.680)	(0.319)	(0.810)	(0.805)
Betweenness Centrality		-6.57e-05		- 0.000446**	- 0.000445**
		(0.657)		(0.0117)	(0.0121)
Eigen Centrality			1.065*	2.453***	2.447***
			(0.0599)	(0.00123)	(0.00136)
Obstacles to cooperate					-0.00622
					(0.960)
Constant	-0.00650	-0.00200	-0.0545	-0.0866	-0.0833
	(0.971)	(0.991)	(0.773)	(0.637)	(0.654)
Observations	55	55	55	55	55
R-squared	0.209	0.212	0.249	0.322	0.322

Robust S.E. in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table A5. Probit models – Dependent variable: Advanced ICT - Total (Linked firms)

	(1)	(2)	(3)	(4)	(5)
Innovation activities	0.383***	0.314**	0.269*	0.426***	0.457***
	(0.00181)	(0.0369)	(0.0808)	(0.00989)	(0.00861)
Area of activity	0.223	0.290	0.496	0.545	0.618*
	(0.236)	(0.222)	(0.166)	(0.147)	(0.0855)
Workforce eduaction	3.771	2.342	3.392	5.395	4.487
	(0.143)	(0.319)	(0.189)	(0.118)	(0.147)
Betweenness Centrality		-8.12e-05		-0.00120*	-0.00107*
		(0.871)		(0.0563)	(0.0987)
Eigen Centrality			11.96**	15.05**	16.61**
			(0.0490)	(0.0153)	(0.0107)
Obstacles to cooperate					-0.706
					(0.182)
Constant	-1.489**	-1.255*	-1.980**	-2.410**	-2.347**
	(0.0150)	(0.0988)	(0.0474)	(0.0231)	(0.0290)
Observations	55	38	38	38	38
Pseudo R2	0.2138	0.1396	0.2567	0.3113	0.3448
Log pseudolikelihood	-29.102798	-20.39108	-17.615534	-16.32171	-15.528341

Robust S.E. in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table A6. Probit models – Dependent variable: Advanced ICT - Selected (Linked firms)

	(1)	(2)	(3)	(4)	(5)
Innovation activities	0.358***	0.300*	0.247	0.389***	0.446***
	(0.00237)	(0.0547)	(0.109)	(0.00884)	(0.00764)
Area of activity	0.215	0.270	0.516	0.552	0.643*
	(0.232)	(0.223)	(0.156)	(0.150)	(0.0815)
Workforce eduaction	0.209	0.361	0.772	0.869	1.092
	(0.393)	(0.268)	(0.626)	(0.539)	(0.480)
Betweenness Centrality		-0.000157		-0.00149**	-0.00144*
		(0.730)		(0.0341)	(0.0712)
Eigen Centrality			14.16**	17.52***	19.56***
			(0.0288)	(0.00845)	(0.00477)
Obstacles to cooperate					-0.747
					(0.160)
Constant	-1.452**	-1.251	-2.091**	-2.390**	-2.431**
	(0.0131)	(0.102)	(0.0400)	(0.0209)	(0.0229)
Observations	55	38	38	38	38
Pseudo R2	0.1635	0.1143	0.2620	0.3440	0.3813
Log pseudolikelihood	-31.697752	-22.149237	-18.455956	-16.395833	-15.47373

Robust S.E. in parentheses
*** p<0.01, ** p<0.05, * p<0.1