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Intertwining innovation and business networks for sustainable agricultural systems: A case study of carbon-neutral beef

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A B S T R A C T

Increasing concerns about climate change and sustainability have been a major challenge for corporations and governments, translating into initiatives to help reduce the environmental impact of economic activities. Innovation networks involving several actors have promoted the adoption of sustainable practices in a deliberate and concerted manner. From a network perspective, initiatives promoted by an innovation network must be incorporated into the existing business network. This study aims to understand how and to what extent innovation and business networks are intertwined to foster sustainable practices in agricultural systems. Therefore, a study of the Carbon Neutral Beef initiative was conducted, which resulted in the development and adoption of standards that ensure carbon balance by integrating livestock and forest production systems. This study supports the notion that the viability of initiatives promoted by an innovation network depends on its overlap with the existing business network. Additionally, the intertwining process may differ in the degree to which it is controlled, thus influencing the exploration and dissemination of integrated practices involving livestock and forest production systems.

1. Introduction

There has been a growing interest in understanding the relevance of business relationships and networks to firm performance and value generation (Ahuja et al., 2012; Baptista et al., 2022; Dagnino et al., 2016; Mueller, 2021; Santos and Mota, 2021; Zhang and Chen, 2022). One reason stems from the need for organisations to access knowledge dispersed across several organisations in an industry (Franco and Esteves, 2020; Gulati, 1999). Given the increasing specialisation of firms, organisations are unlikely to have the capacity to develop, test, and integrate all components and subsystems that constitute an offering (Knickel et al., 2009; Mota and Santos, 2021; Van Mierlo et al., 2010). Thus, research on innovation processes has emphasised cooperation networks between organisations (Najafi-Tavani et al., 2018), and several classifications and typologies have emerged to categorise this phenomenon (Hurmelinna-Laukkanen et al., 2022; Möller and Rajala, 2007; Tatarynowicz et al., 2016).

Research on innovation from a network perspective has discussed the distinction between innovation networks and innovation in business networks (Möller and Rajala, 2007; Rubach et al., 2017). On the one hand, innovation networks, named strategic networks (Amit and Zott, 2001; Gulati et al., 2000), or nets (Möller and Svahn, 2006; Hurmelinna-Laukkanen et al., 2022; Santos et al., 2021) have a deliberate nature and are guided by consensus among its members regarding the objectives to be achieved. These usually involve a hub firm that plays a more active role in the mobilisation and management of the network. On the other hand, a business network is evolutionary, emerging from ongoing interactions between a substantial number of organisations (Axelsson and Easton, 1992). In this context, no firm assumes a central role in the network, although firms may seek to substantially influence the dynamics of that network (Håkansson and Snehota, 1995; Håkansson and Ford, 2002), and innovation occurs within numerous recurring interactions between actors over time (Baraldi et al., 2011; Rubach et al., 2017).

The distinction between these two notions is particularly interesting for the investigation of innovation processes. Deliberate innovation networks enable the analysis of the roles of actors in these networks. However, the dissemination of innovative products or processes in the industry requires overlap between both networks. That is, initiatives promoted by an innovation network must be incorporated into the existing business network (Rubach et al., 2017; Hoholm and Araujo, 2017; Knickel et al., 2009). Despite their importance, particularly when

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the explicit purpose of deliberate networks is to generate and disseminate solutions that involve systemic changes, such as the regeneration of agricultural systems, little attention has been paid to the overlapping of innovation networks and business networks. This study addresses the call for research on the joint dynamics of both innovation networks and business networks (Rubach et al., 2017), aiming to understand how, and to what extent, innovation and business networks intertwine to promote sustainable practices in agricultural systems.

This study uses a case study focusing on an innovation network – the Carbon Neutral Beef (CNB) project – an intentionally created strategic net (Hurmelinna-Laukkanen et al., 2022; Möller and Rajala, 2007) to develop new technological solutions. The growing concern from the Brazilian beef industry towards environmental preservation, international expectations, and the need to meet future demands propelled different actors to join forces in the CNB project, which aimed at managing cattle herds to zero the CO2 emissions bill (Alves et al., 2017).

This study contributes to theory, policymaking, and research by extending previous studies on the overlapping process (Håkansson and Waluszewski, 2007; Hoholm and Araujo, 2017; Hoholm and Olsen, 2012; Rubach et al., 2017). We use the notion of friction associated with the intertwining of innovation and business networks to provide a more nuanced view of mobilisation processes, network orchestration, and innovation brokering. The next section presents a literature review, which discusses agricultural innovation, innovation networks, and business networks. The third section advances the methodological considerations, followed by the fourth section that reports a case study of the CNB project. The fifth section presents a case analysis, and the closing section presents the conclusions.

2. Literature review

2.1. Innovation systems in agriculture

Global population will be approximately 10 billion by 2050, a third more than today. Food production must be increased by 70 % (FAO, 2017). Additionally, agriculture needs to become more sustainable by addressing several issues, such as soil degradation, erosion, excessive use of chemicals, waste of water, and destruction of natural habitats for wildlife (Leeuwis and den Ban, 2004). Thus, agriculture is pressured to produce more while requiring less from the environment (Alves et al., 2017) and ensuring environmental sustainability is pivotal for innovation in agriculture (Bouma et al., 2011).

Agricultural innovation is 'the process whereby individuals or organisations bring newly developed or existing products, processes, or ways of organisation into use for the first time in a specific context in order to increase effectiveness, competitiveness, resilience to shocks, or environmental sustainability, thereby contributing to food security and nutrition, economic development, or sustainable natural resource management' (FAO, 2018). Sustainable development requires a balance between the 3Ps: People, Planet, and Profit (Bouma et al., 2011).

Agricultural innovations can be divided into first- and second-order innovations (Knickel et al., 2009). This distinction relates to the notion of developing innovative processes within a fixed rule set (or paradigm) or adopting new rule sets and paradigms. The pace and intensity of changes in agriculture have required second-order innovations, such as organic farming, and more recently, high-quality, low-quantity regionally specific products. Second-order innovations are required to cope with climate change and resource depletion. New practices or a combination of resources that enable improved production processes are strongly associated with second-order innovation (Knickel et al., 2009).

These innovation processes, which can occur at distinct levels and on different geographical scales (Edquist, 1997; Malerba, 2002; Lundvall, 2016b; Adams et al., 2016), often emerge from the cooperation of several network actors, enabling the flow of knowledge and learning processes (Knickel et al., 2009; Van Mierlo et al., 2010). Rajalahti et al. (2008), for example, emphasised the participation of innovative agents in fostering agricultural innovation, underpinning the interactions between scientific and business communities. Given the landscape and environmental heterogeneity and the economic and social dissimilarities of rural areas, these interactions are of the utmost importance, not only for agriculture, but also for promoting economic development and poverty reduction. Furthermore, access to knowledge by rural producers often requires appropriate organizational configurations. As noted by Knickel et al. (2009, p. 887), innovation"is not only taking place at the level of an individual firm or farm. It may involve a plurality of actors and lead to a reconfiguration of relational patterns".

A broad definition of an innovation system incorporates universities, public and private research institutes, and firms as well as the contexts that affect learning (Asheim and Coenen, 2005; Asheim and Gertler, 2005; Knickel et al., 2009; Adams et al., 2016). In agriculture, the regional dimension is particularly important, given its influence on the processes of generation, introduction, and integration of technologies and knowledge in diverse livestock production systems (Ayele et al., 2012; Spielman et al., 2009). A regional innovation system highlights the link between innovation and the production structure of a specific region. This concept emphasises the importance of regional networks of innovators in the innovation process (Asheim and Gertler, 2005; World Bank, 2006).

The idea of what constitutes agricultural innovation has changed to match the context of agricultural development over time. In the 1980s, National Agricultural Research Systems (NARSs) directed investments mainly to support research at the national level. In the 1990s, Agricultural Knowledge and Information Systems (AKISs), although emphasising knowledge generation, focused on the relationships between research, education, and farmers. More recently, Agricultural Innovation Systems (AISs) have focused on the generation, dissemination, and application of knowledge, focusing on the role and interactions of actors in the public sector, business community, and civil society (World Bank, 2006). These changes over time reflect the prominence of the interaction of multiple actors in generating and applying knowledge.

Research on innovation has long underlined the role of actor interactions. For instance, an 'extremely intricate web of interactions' was found to be pivotal to success in innovation (Rothwell, 1977, p 203). In the same vein, the role of relationships between users and producers in exchanging information and knowledge reinforces the notion of learning-by-interacting (Lundvall, 1985). Learning-by-interacting can depend on actors' cultural and geographical proximity (Ayele et al., 2012; Balland et al., 2015; Frenken, 2020; Lundvall, 1985). In the context of innovation systems know-who becomes particularly relevant as it is often necessary to interact with other actors to know 'who knows what' and 'who knows how' (Lundvall and Johnson, 1994; Lundvall, 2016a).

The notion of interaction is at the heart of appeals for establishing effective links between science and society when pursuing sustainable development in agriculture. For example, TransForum, a national program aimed at stimulating sustainable agricultural development in the Netherlands, emphasised the relevance of the interaction between Knowledge Institutions, Entrepreneurs, NGOs, and Governmental bodies. This national programme occurred between 2004 and 2010 and supported approximately 80 projects (Bouma et al., 2011). Through an analysis of four case studies, Bouma et al. (2011) demonstrated that interaction and knowledge brokering are pivotal to agricultural innovation.

Research institutions, governmental bodies, and firms generate domain-specific knowledge. R&D labs in large companies have made it possible to integrate science and technology; however, critical inputs to the innovation process require the involvement of other actors (Lundvall, 2010). In other words, it involves a "system of interconnected institutions to create, store, and transfer the knowledge, skills, and artifacts that define new technologies" (Metcalfe, 1995, p. 38) and supports their successful adoption and implementation (Roux et al., 2006). In these contexts, the presence of knowledge brokers can help promote the flow of knowledge, as they facilitate interaction between the different actors involved in the innovation process (Bouma et al., 2011; Devaux et al., 2018; Klerkx et al., 2009).

As ecologically sustainable forms of agriculture are relatively complex and knowledge-intensive, they require intensive cooperation among farmers, and between farmers and other stakeholders (Adams et al., 2016; Leeuwis and den Ban, 2004). Thus, from the perspective of Agricultural Innovation Systems, innovation results from a process of networking and interactive learning among actors such as farmers, traders, researchers, technical assistants, government officials, and civil society organisations (Del Río et al., 2010; Klerkx et al., 2009; Van Mierlo et al., 2010).

2.2. Innovation and business networks

The interaction and network approach has focused on cooperative relationships in organizational markets (Araujo and Easton, 1996; Håkansson et al., 2009). Each actor is embedded in a network of direct and indirect relationships with customers, suppliers, distributors, competitors, universities, trade and professional associations, government bodies, and consultants (Easton and Araujo, 1992). As these relationships are interdependent, this implies the emergence of a network structure without a centre and a clear boundary (Axelsson and Easton, 1992; Håkansson et al., 2009). The network is not static; the interaction processes between actors can promote both change and stability in sections of the network. At the level of each relationship, a certain degree of stability is a prerequisite for change to take place. For example, investment in building mutual knowledge and trust may be necessary for two or more actors to commit resources to exploring new technological solutions. Thus, in an overall sense, a business network combines stability and change over time. In other words, interactions between actors, diverse in their competences and interpretations, can constitute a mechanism that generates novelty. This is sometimes in the form of novel combinations of resources and, therefore, innovation. (Anderson et al., 1994; Araujo and Easton, 1996; Håkansson and Snehota, 1989). In this context, relationships are a mechanism, not only to access resources controlled by other actors, but also to develop new resources (Håkansson and Snehota, 1995).

A force that drives change in networks is the ambition of actors to control development in the network. The mobilisation of other actors is essential to influence the network's development, and requires direct (through ownership) or indirect (through relationships) control of resources (e.g. raw materials and exclusivity agreements) (Håkansson and Snehota, 1995). These actions can involve the promotion of a particular interpretation of the network, or even the use of dependency/power relationships to impose a new set of practices. However, greater control of sections of the network by a firm may translate into its lesser opening to accommodate the initiatives and creativity of other actors, and to that extent, contribute to reducing the potential for innovation in the network (Håkansson and Ford, 2002). However, the increase in control of the network by a reduced number of actors can be countered by other actors in the network. According to Håkansson (1992, p. 138), these initiatives can be seen as "a regenerating process where the actors try to utilise new dimensions of resources involved in the network or utilise known dimensions in a new way in the current activities".

The emergent nature of business networks does not exclude the deliberate creation of networks to achieve specific aims, including innovation. These 'ideal types' of networks have been referred to as constructed or innovation networks (Möller and Rajala, 2007; Rubach et al., 2017). Möller and Rajala (2007) proposed a typology of deliberate networks based on two central concepts. The first is the notion of a value system as a set of specific activities conducted by the actors constituting the net. These activities are based on the resources controlled by the actors. The second is the level of determination of the value creation system, that is, the level of codification of the knowledge that supports the activities of the value net. The higher the level of knowledge codification, the lower the uncertainty and the less demanding the network management.

Based on the level of determination of the value creation system, Möller and Rajala (2007) classified nets into current business nets, business renewal nets, and emerging business nets. Current business nets are well-defined and stable value systems that hold well-known actors pursuing efficiency gains. These comprise vertical demand-supply nets, supplier and distribution nets, and horizontal nets. Business renewal nets are positioned at an intermediate level of determination. These often take shape as temporary goal-oriented nets led by hub firms, such as multiparty projects aiming at incremental innovations. Finally, emerging business nets are characterised by low levels of determination. Emerging business nets include application nets, dominant design nets, and innovation networks. These are developed by actors seeking radical innovations and changes in the business value system (Möller and Rajala, 2007; Möller and Svahn, 2006). Innovation networks are technology research networks involving universities, public and private research institutions, and firms that aim to develop new products or business concepts (Möller and Rajala, 2007). Although these are mainly professional self-coordinated networks, innovation networks can take different forms depending on their specific goals, type of interdependence, and level of determinacy.

Based on these dimensions, Hurmelinna-Laukkanen et al. (2022) suggested that innovation networks can be divided into four types: science networks, innovation communities and coalitions, dominant design networks, and applications. The former has the lowest level of determination (e.g. the predominance of tacit knowledge and is more oriented towards exploitation), while the latter has the highest level of determination (e.g. the predominance of explicit knowledge and is more oriented towards exploration). These four network types have different orchestration profiles, and, in general, a firm assumes the role of orchestrator in the innovation network, influencing and managing its development (Hurmelinna-Laukkanen et al., 2022). The hub firm, boundary organisations, and researchers enrol other actors and bring together dispersed knowledge to facilitate and ensure technology brokering (Dhanaraj and Parkhe, 2006; Hurmelinna-Laukkanen et al., 2022; Rubach et al., 2017).

The typology of deliberate networks, which is useful for discussing the type of management challenges in the different nets, does not discuss the dynamic process of intertwining between those networks and the broader business network. It is assumed that emerging business nets turn into business renewal nets and, finally, into current business nets as the knowledge that supports the value system becomes codified. Thus, as innovation network actors perform knowledge creation activities, involving the exploration of technological and commercial opportunities, the diffusion of innovation to other deliberate networks comes down primarily to the issue of the codification of knowledge.

However, the innovation net does not exist in a vacuum, and firms tend to discover new and unexpected associations between practices in different contexts, including their relationships with other actors (e.g. customers, suppliers, government agencies, and R&D units) (Araujo, 1998). Rubach et al. (2017) address the issue of the intertwining between innovation networks, centred on exploration beyond the current core, and the business network, in terms of the overlap between the two. According to Rubach et al. (2017, p. 201), "some disentanglement from embedded business networks may trigger novel ideas and new partnering opportunities, while overlap with established business networks is required to enable innovation in practice". We can use the notion of friction to address the overlap of innovation networks with the business network (Håkansson and Waluszewski, 2007; Rubach et al., 2017). The degree of stability in a business network results from mutual adaptations and significant investments over time (Hoholm and Araujo, 2017). Thus, friction represents the tension between the stability conferred by the existing business network and the destabilisation triggered by innovation processes (Hoholm and Araujo, 2017; Hoholm and Olsen, 2012). It is noteworthy that friction, as a conservative force, may also promote innovation if it does not require significant changes in terms of actors, resources, or activity combinations, such as incremental innovations between interdependent actors (Håkansson and Waluszewski, 2007; Rubach et al., 2017; Prenkert et al., 2022).

From the actor's perspective, friction represents the tension between technical, social, and economic benefits as well as sacrifices required by the actors and their intention to preserve what has already been built by their business over time (Bocconcelli et al., 2020). Additionally, the effects of friction are never local in that they can propagate across the network of direct and indirect relationships with other actors (Håkansson et al., 2009). Therefore, supporting the challenges faced by previously established business networks can be seen as more promising in terms of economic success than trying to start a new network around a supposedly interesting business (Rubach et al., 2017).

In summary, the pace and intensity of agricultural changes require the adoption of new rule sets and paradigms. From the perspective of Agricultural Innovation Systems, innovation results from a process of networking and interactive learning among actors such as farmers, traders, researchers, government or public agencies, and civil society organisations. Moreover, given the landscape and environmental heterogeneity in rural areas, as well as the economic and social dissimilarities, these interactions are crucial in acknowledging and integrating local characteristics into the processes aiming at the development of sustainable agriculture practices, both as a process and as (temporarily) stabilised solutions. In this context, it is often emphasised that hub organisations may have a role in fostering agricultural innovation, underpinning the interactions between the scientific and business communities.

As stated above, innovation networks often play this role, constituting deliberate inter-organizational arrangements involving a specific set of actors with a shared agenda and purpose. From a network perspective, innovation networks may influence the development processes in a business network. The boundaries of the innovation network are permeable, and their relative success requires a degree of overlap with the wider business network.

This study aims to understand how and to what extent innovation and business networks are intertwined to promote sustainable practices in agricultural systems. At the very least, the mobilisation of some companies to join the innovation network and integrate the latest practices into their businesses depends on the degree to which the process of change and expected results of these initiatives contribute to their own interests and capabilities. In other words, the overlapping process between the innovation network and the existing business network entails frictions that can both hinder and facilitate change. This depends on how much new processes or solutions can be positively related by the involved actors to earlier investments in the network.

Aside from a diversity of firm interests, as the innovation network presupposes ambitions to control the innovation process, we suggest that the overlap between the innovation and business networks tends to be selective in nature. In this context, and considering the impossibility of controlling the business network by the innovation network, the question remains as to what extent the selectivity in the overlap between the two networks creates or leaves room for the emergence and testing of variants throughout the innovation process in the wider business network. This aspect is particularly relevant if we assume that what is appropriate for an innovation network is not necessarily helpful from an agricultural system perspective regarding the adoption and adaptation of sustainable practices.

3. Methodology

This study explores how innovation networks develop, and how they affect and are affected by the business network. In-depth examination of how these two networks intertwine allows a better understanding of how an innovation created within the scope of the innovation network is adopted by the business network. Thus, we aim to better understand how innovation in sustainable agricultural practices may (de)stabilise the business network to address the calls for further research and provide knowledge that could orient policy and management actions. We used a process-based case study method (Andersen et al., 2018) to understand how innovation and business networks relate over time. A case study method provides several advantages, as it addresses events and structures in concrete spatial and temporal contexts, progressively constructs the context and limits of the phenomenon, and gradually frames social phenomena in terms of theory (Birkinshaw et al., 2011; Dubois and Araujo, 2004; Easton, 2010; Yin, 2018). We purposely selected our case study (Miles et al., 2014) based on its revelatory potential for this research (Eisenhardt and Graebner, 2007; Siggelkow, 2007).

Further, the selected research setting is particularly interesting for researching the intertwining of innovation and business networks. Brazil, the world's largest beef exporter, intensified its production between 1990 and 2015, with an increase of 229 % (CGEE, 2017). However, this increase in production has led to the burning of the Amazon to expand pasture areas (Embrapa Territorial, 2020). Data from the National Institute for Space Research showed that in 2020, the highest number of fires was recorded in history. Furthermore, livestock and global warming are linked, as the enteric gases released by cattle generate 93 % of all methane from greenhouse gases (GHGs) in Brazilian agriculture.

Several actors from the Brazilian beef industry joined forces in the CNB project, which aimed to manage cattle herds by zeroing the CO2 emissions bill. Briefly, trees introduced into the farming system neutralise the enteric methane emissions of cattle during their production process. The CNB project includes the Brazilian Agricultural Research Corporation (Embrapa) from the Ministry of Agriculture, Livestock, and Food Supply; universities; other research institutions; and several actors from the private sector (Alves et al., 2017).

We followed a systematic combining approach to a case study (Dubois and Gadde, 2002). The casing process began with the analysis of public documents on the chosen case: the Carbon Neutral Beef (CNB) initiative. Interview data were collected between March and September 2020. The deepening of the casing took place through two interviews with innovation brokers who had direct involvement in the bridging process between the two networks. After stabilising the theoretical framework, additional data were collected. In addition to the first two interviews, 10 semi-structured interviews were conducted with informants from other organisations (Table 1). The innovation agency identified participants to examine the connections between organisations (Dubois and Araujo, 2004).

Each interview was recorded and transcribed. Further, we employed secondary data for preparing the interviews and for a more complete understanding of primary data. Secondary data included news, and reports from public and private organisations on the CNB initiative. Articles and books related to agricultural innovation and sustainable practices in agriculture allowed us to better frame the responses of interviewees with distinct roles and at different points in time (Miles et al., 2014; Yin, 2018). We further collected secondary data, such as news and videos shared online that included interviews with researchers from universities and Embrapa, as well as testimonies from farmers and other actors involved in initiatives supported by integrated agricultural systems.

The collected data were analysed by developing a case description regarding the overall purpose of the present research and the conceptual framework. First, we described the meat industry, the emerging business network, and the development of CNB as a brand within the innovation network. This case included concurrent initiatives associated with the overall objective of promoting integrated agricultural systems. As the referrer casing flowed through a systematic combining approach (Dubois and Gadde, 2002), additional data were collected while the theoretical frame evolved to highlight the link between the innovation network and the emergent network. Second, the cases were analysed

Table 1
Interviewees.

Interviewee	Actor role	Date	Length
A	Embrapa	28/03/20	1h18m
B	Embrapa	01/04/20	1h24m
C	Rural producer, owner of rural property, and actor in the scientific community	19/07/20	1h20m
D	Ater – Integrated Crop Livestock Forestry Systems (ICLF) consultant and rural extensionist, from a high-tech region	20/07/20	1h11m
E	Researcher - Actor of the scientific community	21/07/20	1h32m
F	Rural producer, manager of technical rural property and wood agroindustry	22/07/20	1h16m
G	Embrapa	22/07/20	1h12m
H	CNA – Certification management process actor	22/07/20	1h22m
I	Rural producer, owner of rural property, conducting the research pilot project	23/07/20	1h26m
J	Ater – ICLF consultant and rural extensionist, from a low-tech region	29/07/20	1h33m
K	IBD – Certification management process actor	10/09/20	1h13m
L	Marfrig – Actor in the meat industry	17/09/20	50 m

from a network perspective in light of the research aims. That is, extending beyond the deliberate innovation network by including actors, resources, and activities from the wider business network.

4. The story of carbon-neutral beef

4.1. The Brazilian beef industry

The CNB project was born out of the Brazilian beef industry. Brazil's beef industry is currently the largest in the world, both in quantity and financially. This has been achieved, above all, owing to the significant technological changes throughout the agricultural system in the last 40 years. The 1980s were marked by diseases and inconsistencies in the meat supply. Currently, several practices exist, such as artificial insemination, embryo transfer, reduced slaughter time, processes to ensure national supply, and the export market (Moita and Golon, 2014). In addition to the productivity improvements registered on the farms, which represented an increase of 229 % between 1990 and 2015 (CGEE, 2017), a few large companies (slaughterhouses) started to conduct slaughtering, cutting, packaging, and commercialisation of meat, forming an oligopsony (Moita and Golon, 2014).

Meat production is ensured by approximately 2.7 million farms (CGEE, 2017). These farms are heterogeneous, both in dimension and the technological intensity involved, being "dispersed in a continuum that begins with the production of cattle for subsistence, using very simple practices, goes through all levels of technology incorporation until culminating in highly technified productive systems" (Malafaia et al., 2019, p. 122).

Commercial relations between producers and slaughterhouses are primarily centred on the search for low prices, taking advantage of competition between producers. Recent studies suggest that "each farm (farm) works individually and, in a competitive market, is only a price taker, with the final product being characterized as a commodity" (CGEE, 2017, p. 17). The absence of cooperation between producers provides more power to slaughterhouses, substantially influencing the industry (Moita and Golon, 2014). Official reports highlight a context in which conflicts and mistrust between slaughterhouses and farmers predominate (CGEE, 2017). For example, to deal with lags between the weighing of animals by the producer and the buyer, which is sometimes 50 %, some producers feel the need to hire "slaughter watchers" to accompany the process. Additionally, conflicts occur in many other aspects, such as the characterisation of carcasses in terms of fat proportion and wounds.

Some arrangements between producers, such as promoting meat certification, have made it possible to obtain a greater balance in their commercial relations with slaughterhouses. For example, in 2003, the Brazilian Association of Angus launched Certified Angus Beef. The supply of certified animals is guaranteed by the Angus Breeders Association which provides specialised technicians to monitor the process. To use the Angus brand, the slaughterhouse agreed to pay a bonus of around 7 % per unit to producers. The entire traceability process, producer-association-slaughterhouse, is managed by the Brazilian Agriculture and Livestock Confederation (CNA).

In 2009, during the 15th United Nations Conference on Climate Change (COP15), Brazil committed to reducing between 4.9 % and 6.1 % CO2 emissions for agriculture until 2020. However, the goal was very demanding and difficult to meet because "the parameters were European, but [in Brazil] the climate is tropical, and the degradation of organic matter is much faster and much faster because it is much hotter" (Interviewee G, Embrapa).

The growing concern about environmental preservation has driven the creation of Carbon Neutral Beef (CNB) certification by Embrapa. In the Brazilian agriculture industry, Embrapa is a key governmental agency aiming to "make viable solutions for research, development, and innovation for the sustainability of agriculture, for the benefit of Brazilian society". In 2020, Embrapa had 9545 employees, of which 2416 were researchers, 12 % were masters, and 88 % were doctoral. Embrapa plays an integral role in coordinating the National Agricultural Research System, which includes 16 State Agricultural Research Organisations in addition to universities, private companies, and foundations. At the international level, it has bilateral and multilateral agreements with hundreds of other institutions.

In 2010, with the aim of grasping state-of-the-art GHG emissions from beef cattle, Embrapa held the 1st International Symposium on GHGs. In 2011, at a similar event held in Colombia, several models with indicators and metrics to quantify the carbon of the Low-Carbon Coffee NAMA were presented. Following this event, based on their knowledge developed in integrated systems over approximately 40 years, Embrapa researchers began developing the 'equation' to analyse how many trees per hectare would be necessary to offset the GHG emissions of an animal weighing 450 kg.

4.2. CNB: the beginning

The project to create the CNB certification officially began in 2012 and was led by a team from Embrapa Beef Livestock, one of the 42 research centres of Embrapa. CNB is a trademark attributed to beef produced considering the neutralisation of GHG emissions by trees introduced through silvopastoral (Forestry Livestock, IFL) or agrosilvopastoral (Crop-Livestock-Forestry - ICLF) systems. Specific protocols enabling the certification process led to CNB trademark registration by Embrapa at the Brazilian Patents Office (Alves et al., 2017). The CNB certifies that GHGs emitted by the animal's enteric process are compensated for by GHGs captured by the photosynthesis of trees, which will be kept in the wood. For this purpose, a model was developed to assess production systems that can obtain CNB certification. Integrated systems, such as IFL and ICLF, are pivotal to the CNB model.

In 2015, scientific evidence on the developed model was considered satisfactory. It was the first certification for no net release of GHG emissions into the atmosphere in meat production in Brazil and the world (Malafaia et al., 2020). Embrapa was of the opinion that "valuing the scientific knowledge…and even protecting the intellectual property of the CNB certification" were important. An Embrapa team developed and patented the concept brand and published supporting documentation (Villa Alves et al., 2015).

In the same year, and already in possession of a carbon balance model, a pilot project was conducted to make the production of the first experimental batch of animals viable based on the CNB protocol. A partnership was established between Embrapa and the Boa Aguada farm (Mutum Group). This farm, which had already been a pioneer in the implementation of IFL in 2006 and served as an example for other rural producers, could do so again (Suleiman, 2016). Ten other similar projects were implemented in different regions and integrated into the ICLF Network for the dissemination of regionalised data and protocols.

In July 2015, the CNB project was presented to the scientific community at the World Congress on Crop-Livestock Forestry Systems. These reactions showed contrasting results. Researchers in Brazil have on the one hand pointed out that it lags behind local specificities. 'CNB is a European thing… Brazilians want cheap meat" (Interviewee B, Embrapa). Also questioned the economic viability of the idea – "there is no such thing as a trademark-concept". Additionally, integrated production techniques were not new in Brazilian livestock, as "ICLF has been around for I do not know how many years" (Interviewee G, Embrapa). On the other hand, researchers from several countries, namely Japan, Australia, New Zealand, Europe, and Latin America, have shown interest in this project. This international receptivity helped legitimise the project's continuity. Embrapa researchers "saw that international peers were already more adherent than Brazilian ones… those integrated the project, and the project became stronger" (Interviewee G, Embrapa). For Embrapa, the CNB trademark can contribute to increasing the adhesion of producers to ILPF systems and increasing the production of eco-efficient and better-remunerated meat.

4.3. CNB: launching the concept

In 2016, the CNB trademark was officially launched, and the results of the first experimental studies were presented. The business model to be followed for CNB would be similar to that of other certification seals already on the market, such as Carne Angus. The meat would be destined primarily for the international market, being presented as a science-based brand, "in line with what the latest climate science deems necessary to meet the goals of the Paris Agreement" (What are Science Based Targets, 2021). As firms joining the project become part of the Science Based Targets list, in 2020, Marfrig joined the list of nearly 1000 members with Science Based Targets. Thus, Marfrig's product portfolio includes a "science-based" product in line with the MRV (measurable, reportable, and verifiable) concept (i.e., ensuring the transparency of climate change mitigation actions through traceability technologies). According to the Marfrig informant, CNB is "a unique opportunity…that "fits like a glove" on the firm's sustainability pillars.

To ensure process and trademark credibility, the CNB's scientific baselines should be formatted to standards required by the International Organization for Standardization (ISO), and audits should be performed by a third party. Given that at Embrapa, "no one had that expertise" (Interviewee B, Embrapa), in 2017, a technical cooperation contract was signed between Embrapa and the Biodynamic Certification Institute (IBD) to prepare the descriptive and operational certification protocols. IBD has over 30 years of experience in the area and is the largest certifier in Latin America for organic products, with several protocols recognised worldwide.

At the same time, Embrapa began negotiating the right to use the CNB trademark with the slaughterhouses: "They are the ones on the shelves, with access to the consumer. It is not the producer who has access to this public because he does not produce meat; he produces animals. Much less us, from science" (Embrapa). Among these companies, interest lies in those that have international operations, the three main ones being Marfrig, JBS, and Minerva.

In September 2018, a technical and financial cooperation agreement was signed with Marfrig Global Foods. Marfrig is the second-largest multinational in the world in the beef industry, with products sold in approximately 100 countries through distribution centres and commercial offices in the Americas (North and South), Europe, and Asia. Although the details of the agreement are confidential, it is public knowledge that Marfrig acquired exclusive use of the CNB trademark for 10 years until 2030. In return, it pays an annual technological fee and royalties for the products sold (2.5 % of the value of the slaughtered animal). Marfrig declared that it also allocated resources to creating and launching the Viva brand (a CNB line of special meat cuts).

With regard to livestock farmers, Embrapa encouraged the creation of an association between producers close to CNB requirements (i.e. ICLF and IFL). In early 2019, the Brazilian Association of Carbon Neutral Beef Producers (ABCNB) was created with the expectation that slaughterhouses would pay a premium of at least 2.5 % for CNB cattle. However, these expectations have not yet been met. The producers agreed to join the project, ensuring the supply of cattle if Marfrig paid a premium. As for Marfrig, producers should reduce their margins "to make an innovative product viable".

At the end of 2019, the process of creating a network of certifiers interested in providing the CNB seal audit service to rural producers began. Embrapa held the first training Course for CNB Certifiers, including visits to the URT in Quinta Boa Aguada, and involved several organisations, including IBD, Marfrig, ABCNB, and CNA. In early 2020, a cooperation agreement was signed between CNA and Embrapa which, among other aspects, set the prices for certification.

4.4. CNB: hampering sustainability

The Santa Vergínia Agropecuária e Florestal farm, belonging to the Brochmann Pollis Group, was the only farm that joined the CNB project to obtain certification. Under the CNB protocol, Marfrig authorized the slaughter of animals at a single unit in Mato Grosso do Sul near the farm. According to one of the producers, the project's viability may be at stake, as "Marfrig doesn't pay anything, it doesn't have sustainability… it can be nice for marketing, but it doesn't work".

In addition to Marfrig, which has the exclusivity of the CNB trademark, the supply of animals continues to be ensured by one certified farm, Santa Vergínia Agropecuária e Florestal. Of the 30,000 ha of the farm, approximately 8000 ha are already operating in the ICLF system. Of these, IBD certified 904 ha at R$ 7000 per year, granting 400 animals per month. The manager of this farm adds that they intend to reach 20,000 ha of ICLF, reserving around 5000 ha of CCN by 2026.

According to the CNA traceability coordinator, in contrast to other certification programs (e.g. Angus), exclusivity constitutes one of the main restrictions on producer access. In addition to the exclusivity of the use of the CNB trademark and the existence of a single slaughterhouse, the non-adherence of other producers is associated with several aspects. One is related to the integration of forest components with livestock. According to the informant from Marfrig, this aspect gained relevance "as the protocol was implemented and the product was developed". CNB production also poses several challenges for farmers. The producer must guarantee the destination of the wood when adhering to the certification (i.e., between the zero-carbon counting moment and the actual placement of the wood in the market). In other words, according to an informant from IBD, "if he planted a tree today, he has to make a commitment for 15 years to come". This requirement excludes the cellulose production market (cutting the tree in the seventh year), where Brazil is the world's largest exporter. Furthermore, the addition of arboreal components can pose logistical and economic problems. According to one producer, "an ox truck, which costs 60 thousand reais, carries a freight of 5 thousand reais and the slaughterhouse accepts to collect it within a radius of approximately 1,000 km. [In contrast] a wooden truck costs 2 thousand reais and does not support a freight greater than 400 reais, which gives a radius of about 50 km".

To the CNA traceability coordinator, "The CNB is a promising protocol, but it does not have the adhesion we would like to see. Only one supplier is not justified. And systems like ICLF and ICL have been growing". It is not uncommon to find producers certified by the ICLF

Network Association, which aims to increase the economic and environmental sustainability of agricultural units by transferring and sharing knowledge between producers and researchers. This experience shows the importance of the specificities of each farm and the skills and interests of each producer.

4.5. Concurrent developments

In 2010, the Low-Carbon Agriculture Program was launched with the aim of helping Brazil meet the pledge made at the 2009 Copenhagen Climate Conference. This program funds low-interest loans for agricultural activities, improving the soil uptake of nitrogen, and rehabilitating degraded pasturelands, such as the implementation of IFL or ICLF. However, adherence to the program was low. Farmers did not apply for this program as it had stricter environmental requirements than other agricultural loans. Furthermore, the amount allocated per hectare of degraded pasture was considered insufficient, and the bureaucracy for approving agricultural projects was high. In addition, the producers lacked knowledge of sustainable agriculture and livestock practices, such as the integration of agriculture, livestock, and forests.

Embrapa has studied degraded pasture recovery processes and integrated agricultural systems since the 1980s. However, in 2011, Embrapa constituted several research groups to study GHGs in different production systems, namely, in the integration of livestock, forests, and grain cultivation. In this regard, Interviewee B (Embrapa) reports that "everyone talked about the benefits of the ICLF, but no one gained from those benefits. There was no [perception of] real gain... we told the producer that it was all very beautiful and wonderful, but we did not come out of it".

The ICLF Network Association was formed and co-founded in 2012 by private firms and Embrapa, aiming to accelerate farmers' adoption of ICLF technologies to enhance sustainable Brazilian agriculture. In 2012, the area of integration in Brazil was estimated to be approximately 8 million hectares. This partnership promotes the adoption of new practices by the agricultural sector based on Embrapa's competence in integrated agricultural systems. The knowledge transfer and sharing process involved Embrapa teams and farms in various regions of Brazil. Over time, these farms integrated a network of Technological Reference Units (URT), constituting contexts for experimenting with various solutions to improve the environmental and economic sustainability of the units.

The URTs are physical examples of a production system, implemented in reference farms and intended for the validation, demonstration, and transfer of technologies generated, adapted to each region's idiosyncrasies. To publicise ICLF systems and enable the exchange of experiences, these units regularly host events involving other producers and entities that show interest in the technology. In turn, Embrapa and the ICLF Network produce and make available reports documenting the challenges and results obtained in various URT. ICLF technology developed by Embrapa has already been implemented in six Brazilian biomes. The producer profile, regional peculiarities of the biome, and farm are all considered in the ICLF system.

URTs tend to promote cooperation with other local producers and the development of relationships with institutions providing technical assistance to deal with crop-livestock-forest integration, namely planting systems, crop rotation, and forest management. These integrated systems require careful planning in combination with livestock and forest resources in terms of space and time. However, studies suggest that the results of adopting ICLF production strategies are generally positive in economic, environmental, and social terms. As an example, ICFL provides benefits, such as enhanced efficiency in the use of natural resources, productivity improvement, GHG mitigation, soil conversion, animal welfare, reduction of social inequality, flexibility, and adaptability to different contexts. The ICLF Network has been expanding over time, and some producers have launched their own brands to differentiate the meat produced among consumers.

In 2018, the ICLF Network adopted a revised legal structure to become an association. This change aimed to expand activities and facilitate the entry of new companies. There has been a significant increase in the area of ICLF in Brazil. In the 2020/2021 harvest season, the integration area was around 17.4 million hectares (an estimated increase of 52 % in areas with ICLF in Brazil since the 2015/2016 harvest). The ICLF Network has set a goal to double the amount by 2030, reaching around 35 million hectares of ICLF. The adoption of ICFL integration systems is growing because they can be adopted by a wide range of producers, particularly at any technological level. This increase is largely due to R&D efforts combined with technology transfer actions.

4.6. Current panorama

In 2020, Marfrig launched the Viva brand and its own line of meat cuts with a CNB seal. The product is sold in Brazil in specific experimental supermarkets belonging to Grupo Pão de Açúcar, the largest retail firm in the country. Additionally, Marfrig launched the 'Marfrig Verde+ Plan' in partnership with the Dutch institution IDH – Sustainable Trade Initiative, assuming a commitment to have a deforestation-free production chain in 10 years. CNB-labelled meat can be extended to other products. An example is the negotiation between the Marfrig and McDonalds Corporation for the supply of hamburgers.

According to an informant from IBD: "I see that perhaps the CNB will not be a much-used protocol. But has its value for the string in the launch of this concept in the world, and now it is opening the doors to everything. So, I think that now the project has matured. Also, it is not Embrapa's role to limit concepts. Quite the opposite. Its function is to open concepts".

Currently, in addition to the CNB brand, the partnership between Marfrig and Embrapa has been extended to the concept brand of low-carbon beef (LCB) for the certification of meat produced in systems that reduce methane emissions by animals. The LCB is more comprehensive than the CNB, as it dispenses with the forestry component, emphasising the recovery of pasture areas through the integration of agriculture. According to one of the producers, this explains why "83% [of the producers] want to integrate crop-livestock, i.e., without the forest… Crop makes money and the pasture that comes there does not need fertilizer. The forestry component, on the other hand, only enters into 17% of the projects, because they take a long time to pay back". For Marfrig, the LCB brand promises to be "the goose that lays the golden eggs" (Interviewee L, Marfrig), and the development of novel protocols, such as Low Carbon Calf and Native Carbon Beef, is already being considered. These latest projects are also based on integrated agricultural system technology. Table 2 summarises the main events of the Carbon-Neutral Beef story.

5. Discussion

From an industrial network approach, the success of innovation networks requires their overlap with an already established business network. The empirical study illustrates this process over time. The analysis that follows begins by focusing on the emergence and overlapping of the innovation network with the wider network, considering the initiative's initial purposes. Next, we analyse the extent to which, in the wider network, several actors seek to achieve similar purposes, that is, environmentally sustainable agricultural practices and their systemic relevance.

Regarding the creation of the innovation network and its explicit purposes, recall that the innovation network around the CNB trademark initiative was initially formed by a team from a public research institution in agricultural systems. To define a system for neutralising enteric methane emissions of cattle during their own production process by integrating trees into forest plantation activities was the global goal. The Embrapa team, based on its knowledge of integrated systems (ICLF), consolidated the experiences conducted in other geographical contexts

Table 2
Summary of the CNB story.

Year	Main event(s)
1980s	Embrapa has been studying degraded pasture recovery processes and integrated agricultural systems since the 1980s
2009	During the 15th United Nations Conference on Climate Change (COP15), Brazil committed to reducing between 4.9 % and 6.1 % CO2 emissions for agriculture until 2020
2010	The Low-Carbon Agriculture program was launched; Embrapa held the 1st International Symposium on GHGs
2011	At a Symposium in Colombia, several models with indicators and metrics to quantify the carbon of the Low-Carbon Coffee were presented; Embrapa researchers began developing the model to analyse how many trees per hectare would be necessary to offset the GHG emissions of an animal with 450 kg; Embrapa constituted several research groups to study GHGs in different production systems
2012	The CNB project officially began; The ICLF Network Association was formed
2015	Scientific evidence on the model was considered satisfactory; Embrapa patented the CNB concept brand; A pilot project was conducted (for a batch of animals based on the CNB protocol); Ten other similar projects were also implemented in different regions, integrated into the ICLF Network
2016	The CNB trademark was officially launched
2017	Embrapa began negotiating the right to use the CNB trademark with the slaughterhouses
2018	Marfrig granted exclusivity of the CNB trademark
2019	The Brazilian Association of CNB Producers was created; Created a network of certifiers for the CNB seal audit service for rural producers
2020	One producer joined CNB certification (900 ha); Marfrig launched the Viva brand, its own line of cuts of meat with the CNB seal; Marfrig joined the list of nearly 1000 members with Science Based Targets; The partnership between Marfrig and Embrapa has been extended to the concept brand Low Carbon Beef (LCB) - it dispenses with the forestry component; Several producers joined the ICLF network (17.4 million hectares)

and with other products, developing an initial concept of how to mitigate gas emissions.

Subsequently, the beginning of the intertwining process with the business network is manifested in the combination of the concept development context and its testing/production context (Håkansson and Waluszewski, 2007). This occurred through the involvement of a firm, taking advantage of the existing relationship developed over successive joint projects between the farm Boa Aguada and Embrapa. In addition to the Embrapa researchers' unit, the cattle-producing firm, being a URT for ICLF agricultural systems, was essential in conducting tests of different combinations of livestock resources and forest resources for obtaining data that would allow the development, by successive approximations, of a model for evaluating the environmental impacts of these combinations over time.

Having achieved its main purpose, that is, the creation of a model sufficiently validated to be certified and patented as a trademark, its viability as a resource would depend on the dissemination of the CNB, based on ICLF production systems. In other words, innovation in practice depends on the mobilisation of actors in the business network (Rubach et al., 2017). However, despite the knowledge and experience of several actors (Embrapa and producers) in integrated systems, the management of concept dissemination is primarily centralised in one firm, thus playing the role of network orchestrator (Hurmelinna-Laukkanen et al., 2022). Recall that the CNB trademark was, after a negotiation process, attributed exclusively to a firm (Marfrig) responsible for meat cutting and distribution. The firm occupies an extremely prominent position in the network, being one of the four largest operators in the industry with commercial operations in several countries. With its resources and business relationships, this firm could mobilise other actors in the network, particularly producers and retailers. This would ensure the implementation and the concept dissemination in the agricultural system.

With regards to this process, through an agreement with the biggest national food and grocery retailer, the hub firm ensured meat distribution and sales. In contrast, the process of mobilising meat producers–that is, those who can contribute to carbon mitigation in their production activities–presents substantial challenges. It is worth recalling that the expansion of the potential suppliers' base required producers' commitment to carry out a recombination and incorporation of both existing and novel resources and activities into the production system. In this sense, the overlapping process reveals over time several economic, social, and technical frictions (Rubach et al., 2017; Prenkert et al., 2022). For example, according to the GHG neutralisation model, trees can only be cut after several years, and wood from some of these trees will have to be destined for specific applications that exclude burning. The management of these processes, with resources with distinct temporal profiles and final destinations, as is the case for cattle and forests, requires learning over time and routine development. This is not only in production activities but also in producers' involvement in new chains of activities.

It should be noted that when the CNB project was launched, several producers in the business network operated with ILPF systems. In this context, Embrapa through its understanding of the several national biomes, and its experience with local producers, was well positioned to recognise the relevance of specificities in ICLF integration and support the entire process. To promote changes in the producer base by reducing friction (Rubach et al., 2017), Embrapa launched a series of initiatives, including the formation of a producer association, to promote the adoption of ILPF production systems, and thereby develop a base of producers who could apply for certification of their products.

Despite these initiatives, at the business network level, the mobilisation of farmers by Marfrig, a new hub firm, was quite limited. In addition to Marfrig and a retail firm, the CNB project was restricted to a single meat producer. Several aspects seem to explain these results, such as a history of conflicting business relationships between producers and slaughterhouses, the heterogeneity of producers in terms of managerial and technical competencies, the long-term investments (and commitment) required, and the lack of economic incentives both in terms of commercial conditions and production costs.

The exclusive use of the CNB trademark as a resource for an already powerful firm seems to have accentuated the asymmetry in power relations, as noted above. This is characterised by a history of conflicts and a lack of trust between the slaughterhouse and the producers. In practice, the exclusive use of CNB trademarks seems to have reinforced a process in which a limited number of companies seek to control the dissemination of the concept by deciding which producers should be involved. Within this framework, the orchestrator can determine who, when, and how much meat should be produced, according to its objectives. In this sense, it can be said that in the case of the CNB initiative, the overlapping or intertwining between the innovation network and the business network had limited scope. The extent of the intertwining process between the innovation and business networks seems to reflect the ambition to control or orchestrate a small set of actors (Dhanaraj and Parkhe, 2006; Hurmelinna-Laukkanen et al., 2022). Furthermore, by involving a small number of actors and business relationships, the overlap seems to have contributed only marginally to the adoption of more sustainable and economically interesting production practices at the level of the wider business network.

One way to deal with these results, generally seen as too low compared to initial expectations, is to relax the carbon neutrality restriction by registering a new trademark (LCB). Similar to the CNB concept, the exclusive use of LCB was attributed to the same firm (Marfrig). Being more flexible, the expectation of LCB is to substantially increase the adhesion of producers from the existing network. By eliminating the requirement to combine forest plantations with meat production, it is expected that the process of constructing an innovation network around this concept can result in a considerable reduction in the friction associated with the overlapping of the two networks (Håkansson and Waluszewski, 2007; Rubach et al., 2017).

As expected, the CNB initiative shows that it is possible to influence and shape networks (Hurmelinna-Laukkanen et al., 2022; Möller and Svahn, 2003; Möller et al., 2005). The intertwining process around the

CNB trademark occurred, however, in a limited manner, involving the reconfiguration of a smaller number of actors, resources, and activities. This limited impact is particularly evident if one has in mind that the CNB innovation network is intended to increase the value of the producer's cattle (as in Certified Angus Beef) and to develop an economically viable solution for sustainable meat production in a wider network. This suggests that the translation of core business interests into the program of the innovation network (Hoholm and Araujo, 2017) can largely reflect the interests of a very restricted number of actors, the nature of their relationships in the network, and to that extent, substantially condition the process of intertwining or overlapping between networks. The LCB initiative also demonstrates the purpose of maintaining control over the overlapping process, while expanding the base of producers who will potentially be able to accept the commercial conditions imposed by the orchestrator.

However, at the level of the wider network, the relative failure to disseminate more sustainable practices is more apparent than in reality. Considering the dynamics in the business network and the role of Embrapa in those processes, the process of exploration of new practices by producers took place over time in the form of experimentation, the use of new combinations of resources, and more environmentally sustainable activities. As seen in the presentation of the case study, in the business network, a broad knowledge base about ICLF systems was developed over time through a variety of projects involving Embrapa and several producers with URT status. The frictions in the implementation of these variations in the combinations of forest, farming, and livestock reflect local specificities, environmental issues, and actors' interests. The sharing of experiences largely supported using reference units (URT), with the support of Embrapa technicians, seems to lead to a more incremental and distributed development of resource combinations between interdependent actors.

To the extent that these activities are closely related to companies' core business interests, actors can relatively easily assess the benefits and costs of adopting new combinations of resources and activities (Hoholm and Araujo, 2017). Thus, the innovation process also takes place in a more informal and distributed way, permeable to the specificities and interests of various actors operating in the network. This phenomenon occurred despite the presence of a reduced number of actors with substantial power in the network based on the broad direct and indirect control of resources. Instead of innovation brokering centred on an actor (e.g., Devaux et al., 2018; Klerkx et al., 2009), which operates as the network orchestrator (Möller et al., 2005), this role is distributed, and emerges in the context of recurrent exchanges, namely, information and knowledge, between a diversity of actors.

In addition to the co-existence of different approaches to promoting more sustainable practices in agricultural systems, the role of the established business network, characterised by the presence of distributed and emerging interactive processes, has been substantially more relevant than deliberately constructed networks. At the very least, a number of actors who did not join the CNB initiative seem to have contributed to a path or regenerative process (Håkansson, 1992), in which the elimination or reduction of carbon may occur without the control of a central actor. Recall that the incorporation of the forest component into livestock farming systems presents challenges involving new combinations of actors, activities, and resources, as well as in the relationships in which each actor is embedded. Friction at the actor's level manifests itself as a conservative force (Håkansson and Waluszewski, 2007; Rubach et al., 2017), but it also forms the basis for the recognition and exploration of a diversity of solutions in the wider network, for example, manifested in the presence of updated protocols that reflect different approaches to the adoption (and adaptation) of more sustainable practices. In the context wherein each interaction is partly a deliberate action and partly a learning experience, the control of the innovation network built around the CNB contrasts with the degrees of freedom for developing and testing variants in the wider ILPF network.

6. Conclusions

Research on innovation from a network perspective has discussed the distinction between innovation networks and innovation in business networks (Hurmelinna-Laukkanen et al., 2022; Möller and Rajala, 2007; Rubach et al., 2017). From a network perspective, we argue that initiatives promoted by an innovation network need to be incorporated into the existing business network. The requirement for overlapping innovation and business networks is, in our view, particularly relevant when the explicit purpose of deliberate networks is to generate and disseminate solutions that involve systemic changes, such as the regeneration of agricultural systems.

Increasing concerns about climate change and sustainability have been major challenges for corporations and governments, translating into initiatives to help reduce the environmental impact of economic activities. Agricultural systems need to become more sustainable by addressing several issues, such as soil degradation, erosion, excessive use of chemicals, waste of water, and destruction of natural habitats for wildlife (Leeuwis and den Ban, 2004). Innovation networks involving several actors have been promoting the adoption of sustainable practices in a deliberate and concerted manner. This study aimed to investigate how and to what extent innovation and business networks intertwine to promote sustainable practices in agricultural systems.

This study contributes to the literature in several ways. First, our study corroborates the relevance of the overlapping process between the innovation network and the existing network for innovation viability (Hoholm and Araujo, 2017). Studying the CNB initiative centred only on the innovation network (Hurmelinna-Laukkanen et al., 2022; Möller and Rajala, 2007) did not reveal the importance of its overlap with the business network over time (Rubach et al., 2017). This study's empirical context shows that as sustainability improvements may involve several (spatial and temporal) scales and actors, the reach and effects of these initiatives propagate to a wider network, as emphasised in the literature on agricultural innovation systems (Knickel et al., 2009, Ayele et al., 2012; Bouma et al., 2011).

Second, and related to the previous conclusion, the overlapping of the two networks is not friction-free, and its relevance and nature depend, in part, on the competences and interests of the members of the innovation network. These frictions can be economic, social, and technical, as actors combine newly developed resources and activities with those already activated in the network in which they are embedded (Håkansson and Waluszewski, 2007; Rubach et al., 2017). As innovation in practice depends on the mobilisation of actors in the business network (Rubach et al., 2017), the interests of business actors need to be translated into innovation network initiatives. This also implies that the composition of the innovation network may change over time, reflecting the interests and competencies of one or more members of that network. Recall that the mobilisation of specific actors was essential to develop, test, and implement a carbon neutralisation model for the integration of forests and livestock, which was also economically sustainable. The implementation phase was largely centralised in a firm that could leverage its network position to improve it, following current trends for reducing the environmental impact of meat production.

Third, the overlapping of the two networks can occur to an extremely limited extent, similar to the frictions associated with destabilisation caused by new combinations of resources and activities. This seems to be more likely when the translation of core business interests into the program of the innovation network (Hoholm and Araujo, 2017) largely reflects the interests of a limited number of actors. As noted above, the mobilisation of other actors in the network can be highly selective, reflecting both the nature of relationships in the established network and the interests of the orchestrator actor in the innovation network. Recall that the overlap of the innovation network around the CNB with the business network was, to a considerable extent, determined by a single actor. The mobilisation of producers did not occur due to social and economic frictions related to the history of distant and conflicting relationships. This was because a lack of mutual trust prevailed between the orchestrator firm and the network of producers. Therefore, in the context of the diffusion of more sustainable agricultural practices, the social, and economic benefits of innovation networks centred on a hub or orchestrator firm tend to be captured by a reduced number of actors in the business network.

Fourth, from the perspective of dynamics in the wider network, our study suggests that the interactions that occur within a (deliberate) innovation network, largely orchestrated by one actor, can lead to insufficient exploration and loss of variety compared with the exploration of resource combinations in the wider network. The innovation process can take place in a more informal and distributed way, permeable to the specificities and interests of various actors operating in the network. Thus, innovation brokering can be dispersed over several actors, emerging in the context of recurrent exchanges, namely, information and knowledge, rather than being the role of a single actor (e.g., Devaux et al., 2018; Klerkx et al., 2009), which may operate as a network orchestrator (Hurmelinna-Laukkanen et al., 2022; Möller et al., 2005). This aspect is particularly relevant when it is recognised that the integration of forest and livestock systems is subject to many adaptations and experiments in different biomes, with the aim of increasing farm productivity without neglecting improvements in environmental sustainability. This phenomenon manifested itself in our study through the emergence of new protocols that reflect different approaches to the adoption (and adaptation) of more sustainable practices.

In short, this study is in line with research showing that the overlapping process is not frictionless (Håkansson and Waluszewski, 2007; Hoholm and Araujo, 2017; Hoholm and Olsen, 2012; Rubach et al., 2017). This study extends existing research by exploring how friction at the actor's level manifests itself as a conservative force (Håkansson and Waluszewski, 2007; Rubach et al., 2017) but may also form the basis for the recognition and exploration of a diversity of solutions in a wider network. From the perspective of generating more environmentally sustainable solutions, the ambition to control the innovation process by one actor (or a reduced number of actors) does not prevent the regeneration of various practices in the wider network. The history and nature of relationships among actors matter, as they may support the emergence and testing of variants in the combinations of resources and activities, that is, the emergence of innovation in the network.

Regarding implications for policymaking, the present study highlights that innovation in agricultural systems involves a plurality of interacting actors (Klerkx et al., 2009; Knickel et al., 2009). Our study reinforces the notion that mobilising farmers is vital for innovation in sustainable forms of agriculture (Leeuwis and den Ban, 2004), but also suggests that the control of the process by a powerful actor, by preventing adaptations to the idiosyncrasies of farmers and biomes, can hinder the adoption of necessary innovative practices. In the context of integrated agricultural systems, different actors may have a role as knowledge brokers and adapt existing technologies to production and user-specific contexts. Due to the larger and broader implementation of innovative practices in the latter situation, greater economic, environmental, and social sustainability is possible.

Moreover, the nature of business relationships in an established business network may affect the adoption of innovative sustainability measures. As we have seen, previous relational conflicts between powerful intermediaries and producers hindered the reconfiguration of the business network. In a context characterised by distant and conflicting relationships, it is unlikely that actors are willing to invest and commit resources to development paths involving high levels of uncertainty. In contrast, the close relationships between local Embrapa units and small producers create a more favourable context for testing and implementing more environmentally and economically sustainable practices. This is consistent with the notion that "economic and social heterogeneity is a defining characteristic of rural areas and has implications for public policy that supports agriculture as a catalyst for economic development and poverty reduction" (Rajalahti et al., 2008, p. 32).

These issues highlight the need for public innovation policy initiatives to consider multiple contexts simultaneously. That is, the promotion of new practices may not be disseminated to the wider network if these ideas and often conflicting interests are not considered. Assigning to a single actor, however powerful, the management of complex learning and dissemination processes, such as the adoption of more sustainable practices, can inhibit the innovation-generating potential of a wider network. In this context, and as noted by Nelson (2006, 1109), "what is good for the individual innovator is not necessarily good for economic progress viewed more broadly".

Our study has some limitations. It was not possible to explore the relational patterns associated with the diversity of approaches to integrated production systems in depth (Knickel et al., 2009). Our study suggests that the propagation of effects in a wider network can be differentiated, reflecting how actors interpret and seek to deal with the diverse types of friction. In future studies, a finer mapping of this diversity over time (Dubois and Gadde, 2002) may help better understand the relevance of the context-specific nature of the frictions associated with the processes of interconnecting innovation networks to the wider network. Additionally, given the landscape and environmental heterogeneity and the economic and social dissimilarities of rural areas, the reconfiguration of these patterns can be relevant, not only for environmentally sustainable economic development, but also for promoting poverty reduction.

CRediT authorship contribution statement

João Mota: Conceptualization, Methodology, Writing- Original draft preparation. Investigation, Writing- Reviewing and Editing. Jose Novais Santos: Conceptualization, Methodology, Writing- Original draft preparation. Investigation, Writing- Reviewing and Editing. Raissa Alencar: Conceptualization, Writing- Original draft preparation, Investigation.

Data availability

The data that has been used is confidential.

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