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How agricultural exports can revitalise rural areas: evidence from Japanese agri-SMEs

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This study highlights the critical role of export-oriented supply chain integration led by small and medium-sized agricultural enterprises (agri-SMEs) in promoting sustainable rural development. Amid growing concerns about rural depopulation and agrarian decline, an increasing number of agri-SMEs in Japan have sought to expand into international markets. Given their firm embeddedness in local communities, such efforts are crucial for revitalising rural areas and advancing sustainable development. Methodologically, this study adopts a comparative case study design and integrates grounded theory coding (open, axial and selective) with cross-case comparison to analyse 15 semi-structured interviews, company and government documents, and official statistics. This approach allowed the researchers to examine how these enterprises construct and manage export-oriented supply chains and how configurations across the four supply chain steps contribute to rural sustainable development. Findings from the qualitative multiple-case analysis suggest that integrating supply chains into the export of agricultural products can improve the economic performance of agri-SMEs and may also generate socio-cultural and environmental benefits at the meso-level, thereby supporting more sustainable development in rural contexts. By pursuing a dual embeddedness—deeply rooted in local participation and responsive to global market demand—agri-SMEs appear to offer a development model that links export expansion with more inclusive rural development. The findings are broadly consistent with the theory of neo-endogenous rural development.

KEYWORDS

agri-SMEs, exports, rural revitalisation, supply chain management, sustainability

1 Introduction

In today's rapidly evolving global economy, small and medium-sized agricultural enterprises (agri-SMEs) are increasingly pursuing international markets, not only as a strategy for growth but also as a pathway to strengthen rural resilience (Valdés, 2024). These firms play a critical role in rural development by generating employment, fostering innovation and promoting sustainable practices (FAO, 2025). However, the internationalisation of agri-SMEs presents unique challenges. These firms often face barriers, such as limited access to finance, outdated infrastructure, and a lack of managerial expertise to navigate complex global markets (UNCTAD, 2025). Unlike larger multinational corporations, agri-SMEs must overcome significant obstacles to meet the stringent standards of international trade, including quality control, technological innovation, and effective marketing strategies (Valdés, 2024).

Japan's agricultural sector, despite being part of a developed economy, faces profound structural challenges: an ageing farming population, rural depopulation, abandoned farmland, and widening development disparities between urban and rural areas. To address these issues, the Japanese government has positioned agricultural exports as a key strategy for rural

revitalisation (Sakamoto and Iba, 2020). Yet, most academic research on supply chains and rural sustainability remains focused on single-commodity or geographically-specific cases in developing regions, leaving developed economies like Japan underexplored.

This study addresses a gap by examining how agri-SMEs in Japan construct and regulate export-oriented supply chains to boost the competitiveness of Japanese agricultural products in overseas markets and contribute to regional sustainable development. Japan's distinctive institutional, cultural, and geographical context provides a valuable setting for further developing the discourse on sustainable supply chain management and neo-endogenous rural development. Drawing on five case studies of agri-SMEs from rural Japan, this study explores how small-scale enterprises can be integrated into global markets while supporting local socio-economic and environmental resilience.

This study employs an exploratory, qualitative and multiple-case design, primarily based on semi-structured interviews and document analysis. By analysing the case studies of five agri-SMEs from rural areas in Japan, this study focuses on the following questions: 1. How do agri-SMEs build and manage agri-cultural supply chains for export in the four stages of the supply chain (production, processing, distribution/marketing consumption), and what is the impact of these activities on local economic, social-cultural, and environmental sustainability?; 2. What factors contribute to the integration of the above supply chain and its impacts on sustainability? 3. What implications do the above findings have for broader rural sustainable development?

This study contributes to the literature on agricultural supply chains, SME internationalisation and sustainable rural development. It offers practical, context-sensitive insights for both advanced and developing regions facing similar challenges. Its objectives are aligned with several of the United Nations Sustainable Development Goals (SDGs), in particular SDG 1 (No poverty), SDG 2 (Zero hunger), SDG 8 (Decent work and economic growth), SDG 12 (Responsible consumption and production) and SDG 17 (Partnerships for the goals) (United Nations, 2020). By combining local embeddedness with global market orientation, this study offers a new perspective on how rural revitalisation can be pursued in tandem with sustainable development.

2 Literature review

2.1 Japan's agricultural export policy background

Japan's agricultural sector has historically relied on protectionist measures, including price supports, import restrictions and direct subsidies, to maintain rural livelihoods and ensure national food security (Yamashita, 2015). While these policies have provided stability for domestic farmers, they have significantly weakened the sector's international competitiveness and limited agricultural exports (Yamashita, 2015). Despite multiple rounds of policy reforms since the 1980s, Japan's government maintains some of the greatest levels of agricultural support among OECD countries, leading to persistent market distortions and inhibiting the full realisation of export potential (OECD, 2009).

Political and electoral reforms in the early 2000s triggered a gradual policy shift, with the country moving from a defensive,

protectionist stance to an offensive, export-oriented strategy, often referred to as "seme no nosei" (Sasada, 2008). This transition reflected an increasing recognition of the need to enhance Japan's presence in global agri-food markets, especially as the domestic consumption base continued to decline. However, structural inefficiencies, high production costs and fragmented supply chains continued to constrain the international competitiveness of Japanese agriculture.

In response to these challenges, the Japanese government launched the Agricultural Export Expansion Strategy in 2020, setting ambitious targets to achieve five trillion yen in agricultural exports by 2030. The strategy focuses on identifying priority products, strengthening regional branding, improving export logistics and establishing comprehensive support systems to assist producers in penetrating foreign markets (Fujibayashi, 2020). These initiatives aim to increase agricultural exports and serve as a catalyst for broader rural revitalisation.

While national policies have begun to support agricultural exports, the role of agri-SMEs in this transformation remains underexplored.

2.2 Emergence and challenges of agri-SMEs

Amid the evolving policy environment favouring agricultural exports, agri-SMEs in Japan have begun to play an increasingly vital role in connecting local production to global markets. agri-SMEs are recognised for their flexibility, niche specialisation, and rapid adaptation to shifting demands in international markets, particularly in non-grain sectors such as fruits, vegetables, and speciality crops (Yamashita, 2015; Winch and Bianchi, 2006). Unlike large-scale Japanese agricultural cooperatives (JA) and major trading companies, which have traditionally dominated export activities, agri-SMEs offer the potential to penetrate high-value international markets with differentiated products (Okuyama, 2018).

However, these enterprises face considerable challenges in expanding their export operations. The FY2022 JETRO (Japan External Trade Organisation) Survey indicates that 62.4% of Japanese SMEs cited 'difficulty in developing overseas sales channels' as a serious obstacle to internationalisation (Sasada, 2008). A major barrier is the limited access to reliable market information, overseas business networks and international distribution channels, which restricts their ability to make informed export decisions (Winch and Bianchi, 2006; Japan External Trade Organization (JETRO), 2023). High logistical costs, difficulties in complying with foreign sanitary and phytosanitary standards and insufficient brand recognition exacerbate the situation. Although digitalisation offers a pathway to improve operational efficiency and market responsiveness, gaps in digital literacy, infrastructure and financial investment continue to impede widespread adoption among agri-SMEs (Kawane et al., 2023).

Recent government initiatives, such as the Agricultural Export Expansion Strategy launched in 2020, aim to address some of these barriers by offering financial support and export consultation services, as well as facilitating participation in international trade fairs (Sakuyama, 2024). Nevertheless, structural issues, including fragmented production bases and limited horizontal cooperation among SMEs, continue to constrain agricultural producers' ability to achieve the economies

of scale necessary for sustainable export growth. Thus, while agri-SMEs hold significant promise for revitalising rural economies through export-led development, overcoming these structural and strategic challenges remains the key to unlocking the sector's full potential.

However, numerous studies highlight significant opportunities for agri-SMEs. In particular, their comparative advantage over larger firms in export markets often lies in their strong territorial relevance and agile responses to niche market demands, enabling them to thrive internationally despite their limited scale (Hagen et al., 2019; Bennett and Smith, 2002). Furthermore, collective strategies, such as contract farming arrangements, can help small-scale producers meet minimum export standards and ensure consistent supply, thereby lowering barriers to international market entry (Minot, 2011). Through such mechanisms, agri-SMEs and smaller producers can move beyond raw material provision and capture greater value through processing, branding and product differentiation.

Despite persistent challenges such as the cost of export certification, logistical constraints and implementation gaps in policy support, recent technological changes, as well as requirements for more flexibility and speed to market, make the smaller scale of international operations feasible and effective (Agostino et al., 2015; Aslesen and Harirchi, 2015; Massini et al., 2010; Cusmano et al., 2010). Consequently, the role of agri-SMEs as active players forming international linkages has increased (Coviello, 2006; Fernhaber et al., 2007; McDougall et al., 1994; Gancarczyk et al., 2018). Their flexible mechanisms and diversified product and service offerings help attract a younger workforce, and when coupled with national policies, can facilitate youth retention or immigration to rural areas. Nevertheless, rural regions often struggle to retain young people due to limited access to education, affordable housing and well-paying, secure jobs (Kordel et al., 2023; Manta, 2022). This reality suggests that rural revitalisation should not focus solely on economic sectors but instead aim to enhance overall territorial quality of life through place-based, integrated development strategies that include childcare, education and housing security. In this paper, rural revitalisation is used as the English rendering of the Japanese policy concept of *Chiho Sōsei*. The term is widely used in government documents. It refers to policy initiatives aimed at curbing population decline and correcting the excessive concentration of people and functions in the Tokyo metropolitan area, thereby promoting a society in which all citizens can realise diverse forms of well-being. Therefore, fostering the development of agri-SMEs should not be treated merely as a subsidiary of agricultural policy but rather as an integral part of holistic rural strategies, building a supportive social foundation that enhances rural communities' adaptive resilience.

Resilience requires the integration of endogenous action and exogenous support, a phenomenon well established in the Global North literature, especially in Europe (Bosworth et al., 2016; Bosworth et al., 2012; Georgios et al., 2021). agri-SMEs, deeply embedded in local communities, demonstrate notable potential to mobilise cultural resources, traditional knowledge, and grassroots innovation to address rural-specific needs. However, their resilient development remains heavily dependent on external inputs—particularly adequate transport and digital infrastructure—which are critical for connecting to urban and international markets (Stojanova et al., 2022). Hence, a place-based development strategy is essential—integrating agri-SMEs into localised development frameworks while facilitating multilevel

governance and interregional learning networks for coordinated resource mobilisation.

Despite their immense potential—especially in rural contexts—agri-SMEs often face power asymmetries in interactions with government agencies and large corporations, which constrain their agency in strategic planning and resource allocation. Looking ahead, agri-SMEs must navigate not only market volatility but also climate change, evolving consumer demands and rural demographic ageing. This necessitates recognising agri-SMEs as embedded rural societal actors—not merely economic entities. They not only revitalise the rural economy and foster innovation but also play an irreplaceable role in bringing local agri-products to global markets. By leveraging branding, export certification, customer orientation and cross-border e-commerce, these enterprises can overcome traditional export barriers and embed high-quality, territorially distinctive products into global supply chains. In conclusion, this study positions agri-SMEs as a distinct type of enterprise—sharing common themes with the broader SME landscape, yet uniquely shaped by their rural embeddedness, which introduces a set of constraints and opportunities rarely observed in mainstream SME development processes.

This paper illustrates how agri-SMEs contribute to sustainable rural development in Japan by integrating sustainable supply chains, thereby offering a novel perspective on broader debates on sustainability.

2.3 Supply chain for sustainable development

To prepare the groundwork for the subsequent literature review, key terms are defined: 'The supply chain encompasses all activities associated with the flow and transformation of goods from the raw materials stage (extraction), through to the end user, as well as the related information flows. Material and information flow both up and down the supply chain.' Supply chain management (SCM) is the integration of these activities through improved supply chain relationships to achieve a sustainable competitive advantage (Handfield et al., 1999). Sustainable development is defined as 'a development that meets the needs of the present without compromising the ability of future generations to meet their own needs' (Brundtland and Gro Harlem, 1987). As it forms the central theme of this paper, we define sustainable supply chain management as the management of material, information and capital flows as well as cooperation among companies along the supply chain.

In recent years, there has been a growing academic interest in reinterpreting supply chains beyond their traditional economic and logistical functions. Rather than viewing supply chains solely as mechanisms for cost minimisation and efficiency, scholars have increasingly conceptualised them as multidimensional systems embedded within social, environmental and territorial contexts. Elkington et al. (1999) seminal work on the 'Triple Bottom Line' laid the foundation for this shift, arguing that economic performance must be balanced with environmental stewardship and social equity. This can be comprehended as being in line with the notion of order qualifiers, which a company must fulfil before it can even compete for orders (Hill et al., 2000). Still, this is only one particular understanding of sustainability. Dyllick and Hockerts (Dyllick et al., 2002) have framed the three dimensions of sustainability as the

business case (economic), the natural case (environmental) and the societal case (social). Building on this framework, Seuring et al. (2008) (Seuring et al., 2008) developed a comprehensive model of sustainable supply chain management (SSCM) that integrates environmental and social criteria into supply chain design and governance. Their framework, now widely cited, emphasises that sustainable supply chains must address not only product flow but also ethical sourcing, stakeholder inclusion and long-term resilience. In sustainable supply chains, members must meet environmental and social criteria to remain in the supply chain. At the same time, competitiveness is expected to be maintained by meeting customer needs and related economic criteria.

Parallel to this, scholars in rural development and agricultural systems have drawn attention to the concept of sustainable livelihoods. Scoones (1998) proposed a livelihood framework that considers how individuals and communities interact with economic, institutional and ecological systems to secure their well-being. This perspective has informed numerous studies of agri-food supply chains, particularly in the Global South, where the roles of local agency and adaptive capacity are critical. Similarly, Darnhofer et al. (2012) emphasised the need for farming and supply systems to be territorially embedded, socially responsive and ecologically adaptive, calling for more context-sensitive approaches to resilience and innovation.

In summary, it is evident that green/environmental issues still dominate research. Studies that incorporate the social aspects of rural sustainable development remain rare.

2.4 Agricultural exports for sustainable rural development

With the increasing interconnection of the global economy and the growing openness of markets, Japan's agricultural development strategy has gradually shifted from a traditional domestic demand orientation to an active expansion into overseas markets. Agricultural exports are now increasingly seen as a key driver for rural revitalisation in Japan.

The literature shows that strengthening the link between agricultural exports and rural revitalisation policies not only supports short-term economic growth but is also essential for the long-term sustainable development of rural communities in Japan.

Bairak and Hughes (1996) pointed out that agricultural exports have significantly enhanced rural economic development. Increasing the export of farm products, especially processed products, can substantially boost rural economic activity. Similarly, Roberta et al. (2021) used social network analysis and found that in Foggia Province, Italy, the export structure of agri-SMEs had improved significantly in recent years, thereby enhancing the region's economic vitality.

Similarly, Taniguchi (2006) conducted a case study on the export of high-value agricultural products from the Nishiwami area of Japan. The study showed that although the export scale was limited, it effectively raised the region's visibility, indirectly increased local market demand, and improved the region's overall economic level.

Kabuta (2023) pointed out that the export of Japanese agricultural and fishery products, as well as inbound tourism demand, significantly contributed to the food industry's economy. In particular, amid declining population and slow economic growth, exports have become an important path to sustainable development for local economies.

In addition, Chen et al. (2022) developed an evaluation system to measure the coupling and coordination between agricultural modernisation and regional economic development. By analysing data from 31 provinces in China, they found a strong coupling relationship between the two, further highlighting the long-term importance of agricultural exports for regional development.

However, to ensure that these beneficial effects continue over the long term, it is necessary to establish a stable regional export system and a well-developed policy support framework. Taniguchi (2006) particularly noted that although demand for high-value agricultural products in East Asia is rising, limited infrastructure and market networks in rural areas may affect the sustainability of exports. Therefore, it is imperative to strengthen collaboration among governments, businesses, and communities. The administration has played a vital role in invigorating less-favoured areas in Japan (Yamashita et al., 2010).

Thus, strengthening the linkages between agricultural exports and regional revitalisation initiatives represents not only an economic imperative but also a vital policy direction for ensuring the long-term sustainability of Japan's rural communities.

2.5 Analytical approach

This study constructs a conceptual and analytical framework to reveal how agri-SMEs lead the integration of sustainable supply chains in the context of agricultural export. The framework highlights that practices are shaped by interactions among social actors, territorial resources, the institutional environment, and socio-cultural structures, rather than the result of isolated business decisions. Accordingly, this study treats supply chains as dynamic processes embedded within socio-ecological systems, rather than as abstract economic models.

In export-oriented supply chains, agri-SMEs are not merely passive participants but emerge as key coordinators, actively leading integration through origin-based collaboration, logistics coordination, quality control and demand alignment. Such integration goes beyond the linear structure of 'production-processing-marketing'. It is shaped by local institutional contexts (e.g., regional branding, agricultural policy support) and social relational networks (e.g., farmer cooperatives). Therefore, the analytical unit in this study is not the individual firm but the agri-SME-led 'sustainable supply chain collaboration network'. These networks span all stages of the supply chain, from production to export, and reflect how agri-SMEs couple organisational structures across regions and proactively reshape governance logic within the supply chain.

In summary, the sustainable supply chain governance capacity of agri-SMEs is crucial not only for improving export performance but also as a core pathway for advancing rural revitalisation and enhancing regional resilience.

However, most academic studies on sustainable supply chain governance focus on specific case studies or isolated segments or products, lacking a comprehensive understanding of how agri-SMEs integrate environmental, social and economic dimensions to drive sustainable transformation in export-oriented agricultural supply chains. To address this gap, this study adopts 'embedded supply chain governance' as its core analytical lens, examining how agri-SMEs construct and integrate sustainable agricultural supply chains by leveraging local resources, social relations, and institutional

frameworks. Special attention is given to the ‘dual embeddedness’ model—rooted locally to leverage geographic, cultural and institutional advantages for product differentiation and competitiveness while simultaneously aligning with international standards and consumer preferences through review mechanisms such as direct feedback, organic certification and traceability systems.

This study aims to answer the following questions:

1. Discuss how agri-SMEs build and manage the agricultural export supply chain during the four stages of the supply chain (production, processing, distribution/marketing, consumption) and analyse the sustainability impacts these activities have on local communities in terms of economic, socio-cultural and environmental value.
2. What factors can contribute to the integration of the above supply chain and the benefits it has on sustainability?
3. What implications do the above findings have for broader rural sustainable development? This study adopts a multi-case comparative approach, focusing on a range of export-oriented agri-SMEs with robust territorial embeddedness to address current gaps in sustainable supply chain governance research.

3 Materials and methods

This section outlines the case studies used to inform the observations, as well as the data collection and analysis methods. This research constitutes an exploratory study based on interpretative analysis of export-oriented supply chains dominated by agri-SMEs and does not seek to adopt a complete explanatory approach.

3.1 Research design

This article results from comparative case study research (Eisenhardt, 1989) focused on five agri-SMEs in four Japanese rural areas. Information-rich cases were prioritised to uncover relevant mechanisms rather than to estimate population averages. This form of research is a strong approach for contextualised understanding because it offers valuable insights into patterns, differences, and broader trends across the different contexts (Dooley et al., 2020). It extends qualitative insights beyond a single case and enables cross-case learning (Runeson and Höst, 2009). However, this approach also presents challenges, including the complexity of the analysis, the need for a rigorous framework to ensure meaningful comparisons, and potential limitations arising from variations in data quality and availability (Pacwicz, 2022). Also, while cases may share similarities, their unique historical, cultural, and economic contexts can complicate direct comparisons and lead to overgeneralisations (Bayeck, 2023). Despite these challenges, a well-structured comparative case study analysis remains an effective method to examine social-, economic-, and policy-related phenomena (Runeson and Höst, 2009).

This article employed a multiple-method data collection strategy to ensure a comprehensive, credible, and contextually grounded understanding of the practices of agri-SMEs engaged in agricultural exports in Japan. Data was gathered through semi-structured interviews, company documents, government reports, and secondary data sources.

Before selecting focal enterprises for investigation, a broad preliminary screening was conducted to identify suitable cases. The screening criteria for enterprises were:

1. verifiable agricultural export records,
2. located in a rural area of Japan,
3. recognised or awarded for excellence in export activities or supply chain innovation by the Ministry of Agriculture, Forestry and Fisheries (MAFF); and,
4. exporting commodities prioritised in MAFF’s export promotional strategy.

Through this rigorous process, five agri-SMEs were selected as shown in Table 1: (i) the Neighborhood (Miyazaki Prefecture, Miyazaki City), specialising in citrus fruit exports; (ii) the Kushima Aoi Farm (Miyazaki Prefecture, Kushima City), specialising in sweet potato exports (Kushima AOI Farm Co., Ltd, 2024); (iii) Nihon-agri (Aomori Prefecture), specialising in apple exports (Nihon-Agri, 2024); (iv) Obihiro-Kawanishi JA (Hokkaido), specialising in yam exports (Obihiro-Kawanishi JA, 2024); and (v) Yuzuoukoku (Kouchi Prefecture), specialising in yuzu exports. Figure 1 illustrates the geographical distribution of the case study sites.

3.2 Analytical framework: outcome dimensions and explanatory conditions

This study builds on the template structure and focuses on each stage of the supply chain, sustainability outcomes, including:

Economic outcomes: employment rates relative to the surrounding region; number of employees; comparison of average wages with the national minimum wage; perceptions of livelihood viability; profiles of participating actors; local retention rate of export earnings; and the contribution of supply chain integration to national GDP. Where available, fundamental quantitative indicators (e.g., the number of employees and export volumes) were collected. However, data availability varied across the cases; therefore, quantitative figures are reported descriptively and not used for statistical comparison.

Socio-cultural outcomes: Accessibility of territorial capital to agri-SMEs when building export-oriented supply chains; levels of trust and cooperation; sharing of local capital; human–environment interactions; and demographic patterns of supply chain actors in terms of education, age, gender and migration status.

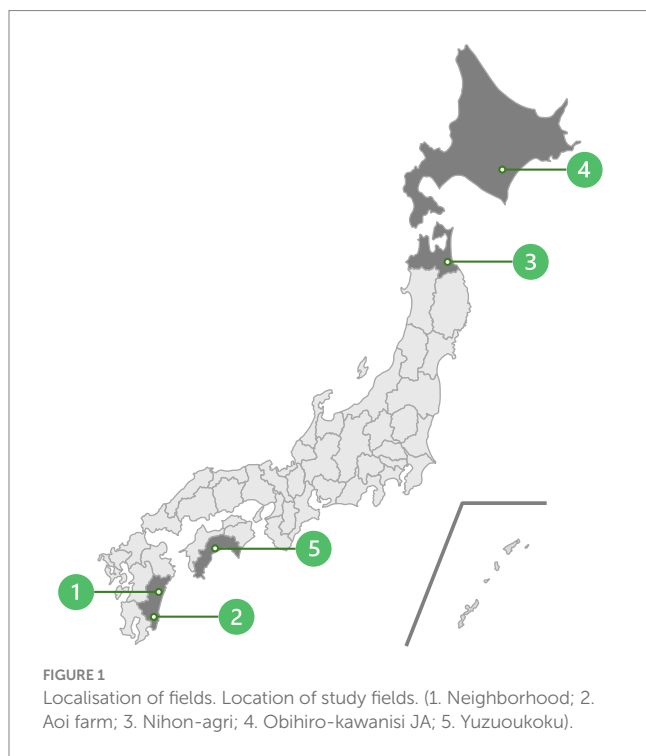
Environmental outcomes: Competition for natural and agricultural resources; sustainable resource use; pollution; and greenhouse gas emissions.

These outcome criteria address the crucial themes in the existing literature on agricultural and rural development and reflect a multidimensional assessment approach that extends supply chain performance evaluation beyond purely economic indicators to include socio-cultural and environmental dimensions. To further explore the differentiation and embeddedness of supply chain integration, the study also recorded key contextual variables, including:

- Whether the final agricultural products represent the locality, with features such as geographical indications or traditional farming techniques;
- The intensity of demand and competitive structure in export markets;

TABLE 1 Overview of selected cases and selection criteria.

Case	Product	Location	Main supply chain features	Main territorial capitals
Neighborhood	Citrus	Miyazaki Prefecture	Seasonal relay system, direct export	Diverse economic institutions, knowledge, social capital, cooperation
Kushima Aoi Farm	Sweet potato	Miyazaki Prefecture	Vertically integrated supply chain, contract farming, cooperative network	Diverse economic institutions, knowledge, social capital, local varieties, landscape, agricultural infrastructure, processing units
Nihon-agri	Apple	Aomori prefecture	Direct export, own packing facility	Diverse economic institutions, knowledge, skills, cooperation, landscape, local varieties
Obihiro-Kawanishi JA	Yam	Hokkaido	Regional brand operation capabilities	Agricultural infrastructure, tradition, community support, protected habitats and local species Diverse economic institutions,
Yuzuoukoku	Yuzu	Kouchi Prefecture	Traditional cooperative distribution system, high value-added agricultural product chain, village symbiotic supply system	biodiversity, climate, local varieties, tradition, agricultural infrastructure, knowledge, cooperation, designated product and export-compatible



- The business models of agri-SMEs (including organisational structures and firm size).

Although several cases provided detailed background information, variation in data availability restricted the scope for systematic quantitative comparison; therefore, cross-case analysis is primarily based on qualitative patterns rather than standardised indicators.

3.3 Data collection and analysis

Figure 2 illustrates the four key stages of the supply chain: production, processing, distribution and marketing, and consumption. Each stage relies on territorial resources, socio-cultural and environmental factors, practices, and actors, with the majority of activities being led by agri-SMEs.

Primary data were gathered through 15 semi-structured interviews with senior managers, export coordinators, and supply chain stakeholders from each enterprise. Guided by a theoretical framework, interviews focused on operational capabilities, supply chain integration, export strategies, external support, and regional impacts. Each interview session lasted approximately 60–90 min, and was conducted either face-to-face or online. All sessions were audio-recorded and transcribed with the participants’ informed consent. The study was approved by the Ethics Committee of Mie University and conducted in accordance with ethical research standards. Table 2 summarises the types of stakeholders interviewed across the five cases, showing the diversity of organisational perspectives represented in this study.

In this study, NVivo 14 was used to conduct grounded theory coding on 15 interviews from 5 cases, following 3 stages: open coding, axial coding and selective coding.

Open coding included a comparative analysis of the raw case materials to extract concepts and categories closely related to the research theme. During the concrete coding process, this research highlighted the overarching question of how the configuration of export-oriented supply chains promotes rural sustainable development and, drawing on the theoretical review, posed the following questions to the case study enterprises: 1. Discuss how agri-SMEs create and manage agricultural supply chains for export in the four stages of the supply chain (production, processing, distribution and marketing consumption), and analyse the effects of these activities on local economic, social-cultural and environmental sustainability?; 2. What

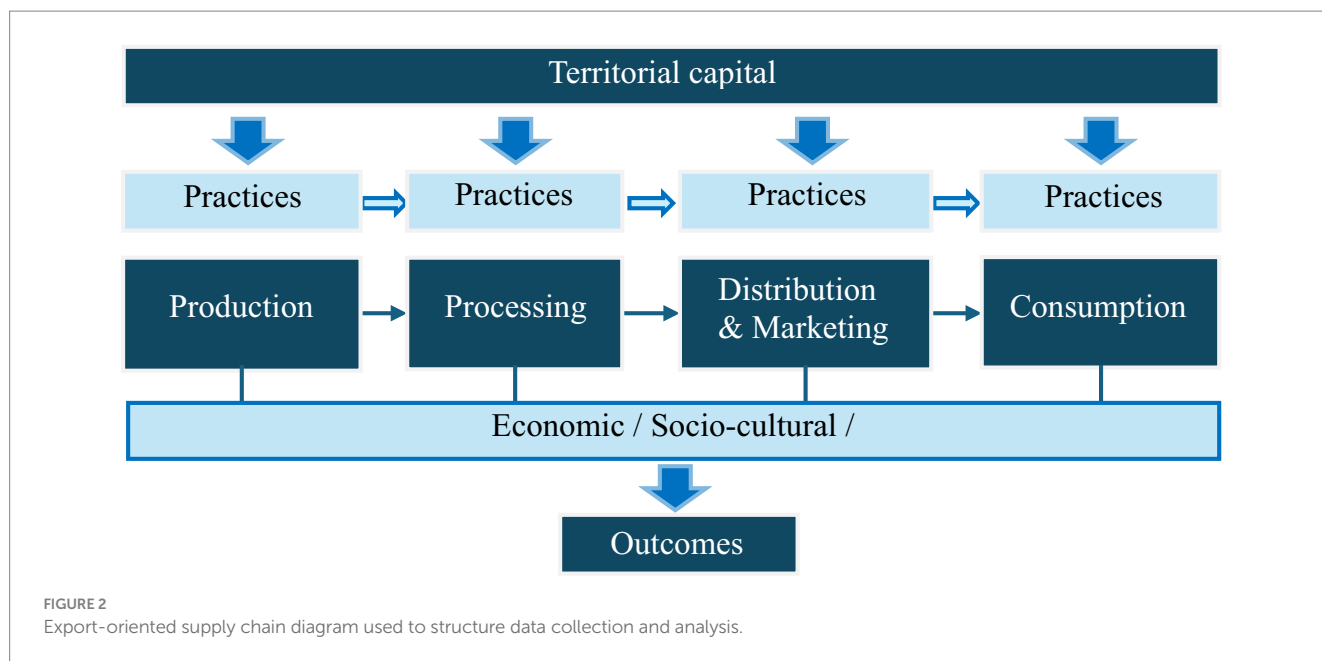


FIGURE 2 Export-oriented supply chain diagram used to structure data collection and analysis.

TABLE 2 Summary of interview participants and stakeholder composition.

Company name	Total interviews	Dates	Senior managers	Export coordinators	Public authority	Cooperative farm
Neighborhood	3	2024.11	1	1	0	1
Aoi farm	3	2024.11	1	1	0	1
Nihon-agri	3	2024.2	1	1	0	1
Obihiro-kawanisi JA	3	2024.2	1	1	1	0
Yuzuoukoku	3	2024.2	1	1	1	0
Total	15		5	5	2	3

During a preliminary pilot study, interviews with officials from the Tsu City Government in the Mie Prefecture were also conducted, including representatives of the Mie Prefecture JA Central Union, mandarin orange growers in Mie Prefecture, a Kujo-negi (Kyoto scallion) producing and processing enterprise in Kyoto, and export officers from the Yamanashi Prefectural Government. These interviews were not included in the formal case analyses because the local impacts of export-oriented supply chains could not be clearly identified at that stage.

factors contribute to the integration of the above supply chain and its implications on sustainability? After the audio recordings were transcribed verbatim, the textual data were subjected to detailed coding and analysis. By inductively grouping and consolidating the original interview statements, 34 initial concepts were identified and further distilled into 12 core categories.

The primary purpose of axial coding is to probe further and analyse the initial concepts and basic categories generated through open coding, and to identify the underlying logic and interrelationships among these basic categories to construct higher-order categories. Based on the 12 basic categories identified in open coding, 4 main categories were derived: (1) market-oriented product and process upgrading (UPG); (2) organisation of the supply base and supply chain governance (SOG); (3) responses to institutional and risk environments (INR); and (4) territorial embeddedness and entrepreneurial agency (TEA).

The primary categories derived from axial coding address the first research questions above. At the production and processing stages, the agri-SMEs focus on product upgrading, supply, and governance by adjusting varieties, packaging, and processing methods to fulfil export requirements, while organising contract farmers, collaborative

production, and shared facilities to secure a stable, high-quality supply. At the distribution/marketing and consumption stages, they rely on supply and governance, along with institutional and risk management, and combine trading companies, agricultural cooperatives (JA), and direct exports to diversify export channels and comply with relevant standards. At the same time, they draw on TEA by mobilising regional brands, government support and local networks. Taken together, these configurations appear to support increases in farmers' income and employment, may strengthen place-based identity and trust, can help reduce losses from product spoilage, and tend to encourage more quality- and environment-oriented farming practices, thereby potentially contributing to economic, socio-cultural, and environmental sustainability.

The primary task of selective coding is to analyse the relationships between the primary and related categories, distil a core category, and develop a coherent storyline that underpins the theoretical model. In this study, the core category derived from the grounded theory analysis is the configuration of export-oriented supply chains that enables rural sustainable development. After completing selective coding, the three reserved case interviews were coded to test for theoretical saturation. The additional coding revealed no new

categories beyond those identified in the previous stages, and repeated checks and comparisons of the data did not yield any additional concepts or categories. Accordingly, the coding results were ascertained to have reached theoretical saturation. Based on the core category, the interrelationships between the primary categories and core categories were further synthesised to construct a configuration model, as illustrated in Figure 3.

To enhance the credibility of the analysis, the first author conducted the primary coding. Next, the co-authors reviewed the evolving codebook and a subset of coded transcripts. Discrepancies in code application and category boundaries were discussed in joint meetings and resolved through negotiated agreement, leading to the further refinement of the code definitions. This process of researcher triangulation helped to decrease individual bias and stabilise the coding scheme.

To complement interviews, internal documents were analysed, such as marketing materials, export reports, and supply chain diagrams. Relevant government policies, including the MAFF’s Agricultural Export Expansion Strategy (Ministry of Agriculture, Forestry and Fisheries, 2023), were also reviewed to situate findings within a broader policy context. Additionally, secondary data from industry publications, trade journals, firm documents, cooperative reports, and official export statistics from MAFF and JETRO were used to validate and enrich the primary data. To enhance analytical rigour, the study employed a cross-case comparison method to identify similarities and variations among the five firms. Triangulation of data from multiple sources enhanced the reliability and validity of the findings (Neighborhood Corporation, 2024; Yuzuoukoku, 2024). Consistencies across these sources strengthened the validity of the interpretations, whereas discrepancies were carefully examined to avoid overgeneralisations.

To deepen our understanding of the integration processes and outcome management of agri-SMEs within export-oriented sustainable supply chains, this study conducted a comparative analysis across multiple cases. Local research participants responded to a standardised interview template and compiled case reports based on interview content. These five supply chain cases were then synthesised to extract

embedded integration patterns, local resource utilisation strategies, and descriptive insights into multidimensional sustainability performance.

Given the volume of information contained in the fifteen interviews, the analysis focused on selected aspects of the data corpus. Due to the heterogeneity of data sources and case contexts, no quantitative analysis was performed. All numerical values reflect only the conditions of the respective cases and are not intended to suggest generalisability beyond the five focal supply chains.

To assess economic, social, and environmental outcomes across supply chain stages, the study examined contextual variables, including product type, market competition structure, and business models. Narratives of perceived outcomes in interviews were also analysed to identify potential patterns or account for the absence of clear commonalities.

4 Findings: outcomes and possible explanations

This section builds on the configuration model developed in Section 3.3 (Figure 3). It draws on stakeholder perceptions from 15 interviews conducted across the 5 enterprises to examine in greater depth how export-oriented agricultural supply chains affect rural sustainable development and what factors shape these effects, thereby addressing the second part of Research Question 1 and Research Question 2. Table 3 presents a cross-case summary of these outcomes, operationalised through a set of economic, socio-cultural and environmental factors, and serves as a point of entry into the more detailed case narratives that follow.

4.1 Main integration initiatives and economic outcomes

Supply chain analysis focuses on the entire process from production to consumption. Its core elements involve the efficient coordination and flow of materials, information, and capital. Emphasis

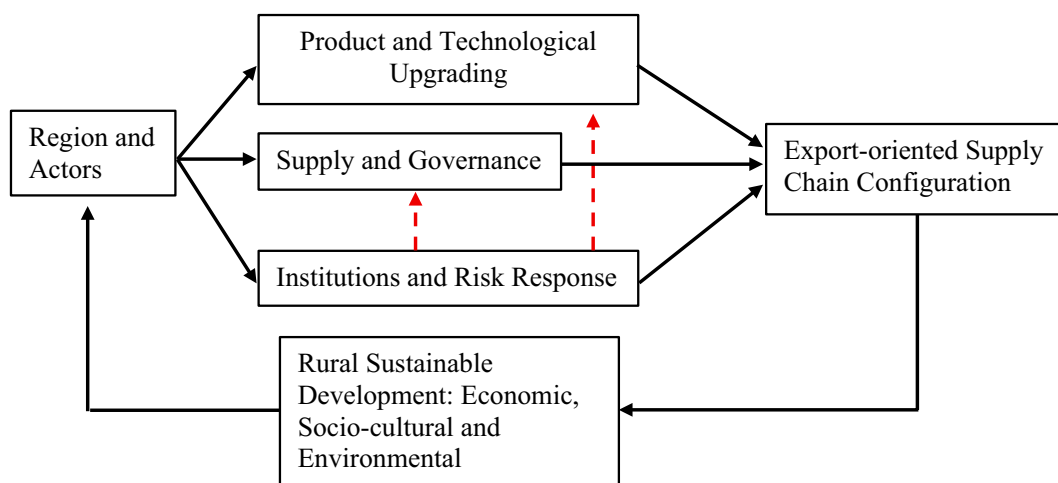


FIGURE 3 A configuration model for export-oriented agricultural supply chains to promote sustainable rural development.

TABLE 3 Cross-case summary.

Case	Economic factors					
Factors	GI and territorial brand	Premium prices	Cooperative business models	Support from public policies	Small-scale business	Competition for resources
Neighborhood	△	✓	✓	△	✓	✓
Aoi Farm	△	△	✓	△	✓	✓
Nihon-Agri	✓	△	✓	✓	✓	✓
Obihiro-Kawanishi JA	✓	✓	✓	✓	△	△
Yuzuoukoku	✓	✓	✓	✓	✓	△
Case	Socio-cultural factors					
Factors	Use of traditional practices and knowledge	Access to land and other factors of production	Cooperation and collaboration	Characteristics of SMEs	Conflict with public institutions	
Neighborhood	△	✓	✓	✓	✓	
Aoi Farm	△	✓	✓	✓	✓	
Nihon-Agri	✓	✓	✓	✓	△	
Obihiro-Kawanishi JA	✓	✓	✓	△	△	
Yuzuoukoku	✓	✓	✓	✓	△	
Case	Environmental factors					
Factors	Certification standards	Export restrictions	Market needs	Information sharing between farmers		
Neighborhood	△	✓	✓	✓		
Aoi Farm	△	✓	✓	✓		
Nihon-Agri	△	✓	✓	✓		
Obihiro-Kawanishi JA	✓	✓	✓	✓		
Yuzuoukoku	✓	✓	✓	✓		
Case	Economic outcomes					
Outcomes	Local employment	Income	Improved production efficiency	Local quality food or commodity	Contribution to national economic development	
Neighborhood	✓	✓	✓	△	△	
Aoi Farm	✓	✓	✓	△	△	
Nihon-Agri	✓	✓	✓	✓	△	
Obihiro-Kawanishi JA	✓	✓	✓	✓	✓	
Yuzuoukoku	✓	✓	✓	✓	✓	
Case	Socio-cultural outcomes					
Outcomes	Preserving traditional agricultural products and cultivation knowledge	Social connections and trust	Opportunities for local people, including women, youth and immigrants			
Neighborhood	△	✓	✓			
Aoi Farm	△	✓	✓			
Nihon-Agri	✓	✓	✓			
Obihiro-Kawanishi JA	✓	✓	✓			
Yuzuoukoku	✓	✓	✓			

(Continued)

TABLE 3 (Continued)

Case	Environmental outcomes		
	Eco-friendly land management	Reduces losses	Climate change mitigation
Neighborhood	✓	△	✓
Aoi Farm	✓	✓	△
Nihon-Agri	△	✓	△
Obihiro-Kawanishi JA	✓	✓	✓
Yuzuoukoku	✓	△	△

A check mark means that the respondents in the surveyed company perceived the factor or outcome. In contrast, a triangle indicates that the respondents of the surveyed company did not perceive the factor or the outcome.

GI: Japan's geographical indication protection system.

is placed on improving efficiency, building resilience, and enhancing value transmission across the supply chain. Consequently, the initial phase of outcome generation centres on economic development, even when such development is not directly expressed in terms of financial returns (Figure 4).

Instead, the emphasis lies on employment generation, livelihood viability, and contribution to national economic growth. The observed economic outcomes are primarily manifested as private benefits; however, support for high-quality local food production can also be interpreted as a public benefit.

4.1.1 Perceived changes in the territorial economic capital base

Firstly, all cases reported an increase in economic capital following supply chain integration, primarily reflected in improved revenue generation for core enterprises. Case analysis suggested that territorial economic gains were closely associated with robust place-based branding strategies (including Geographical Indication [GI] registration), the production of high-value-added products, diversified aggregation and logistics mechanisms, and synergistic interactions with other regional activities. As several interviewees emphasised, the construction of export-oriented supply chains significantly improved both business stability and local income circulation.

“Through direct export, we can stabilise our income and plan production for the next season with more confidence. The domestic market fluctuates a lot, but overseas demand provides a sense of stability.”

— Interviewee A, Neighborhood Co., Ltd., Miyazaki Prefecture.

Another respondent further pointed out that product differentiation and regional branding enhanced market recognition:

“The GI registration has helped us gain trust from overseas customers. They now associate our region's name with quality and reliability.”

— Interviewee B, Obihiro-Kawanishi JA, Hokkaido Prefecture.

While certain agri-food supply chains demonstrated strong performance in terms of export growth, stable supply, and enhanced value addition, external shocks—such as the COVID-19 pandemic and the Russia–Ukraine war— exerted negative impacts on the broader regional economy, especially in areas related to export volume and investor confidence. Accordingly, some cases also expressed broader concerns regarding the long-term trajectory of regional economic development.

“During the COVID-19 period, overseas orders almost stopped for several months. Even after reopening, logistics costs were extremely high, and we could not secure containers on time.”

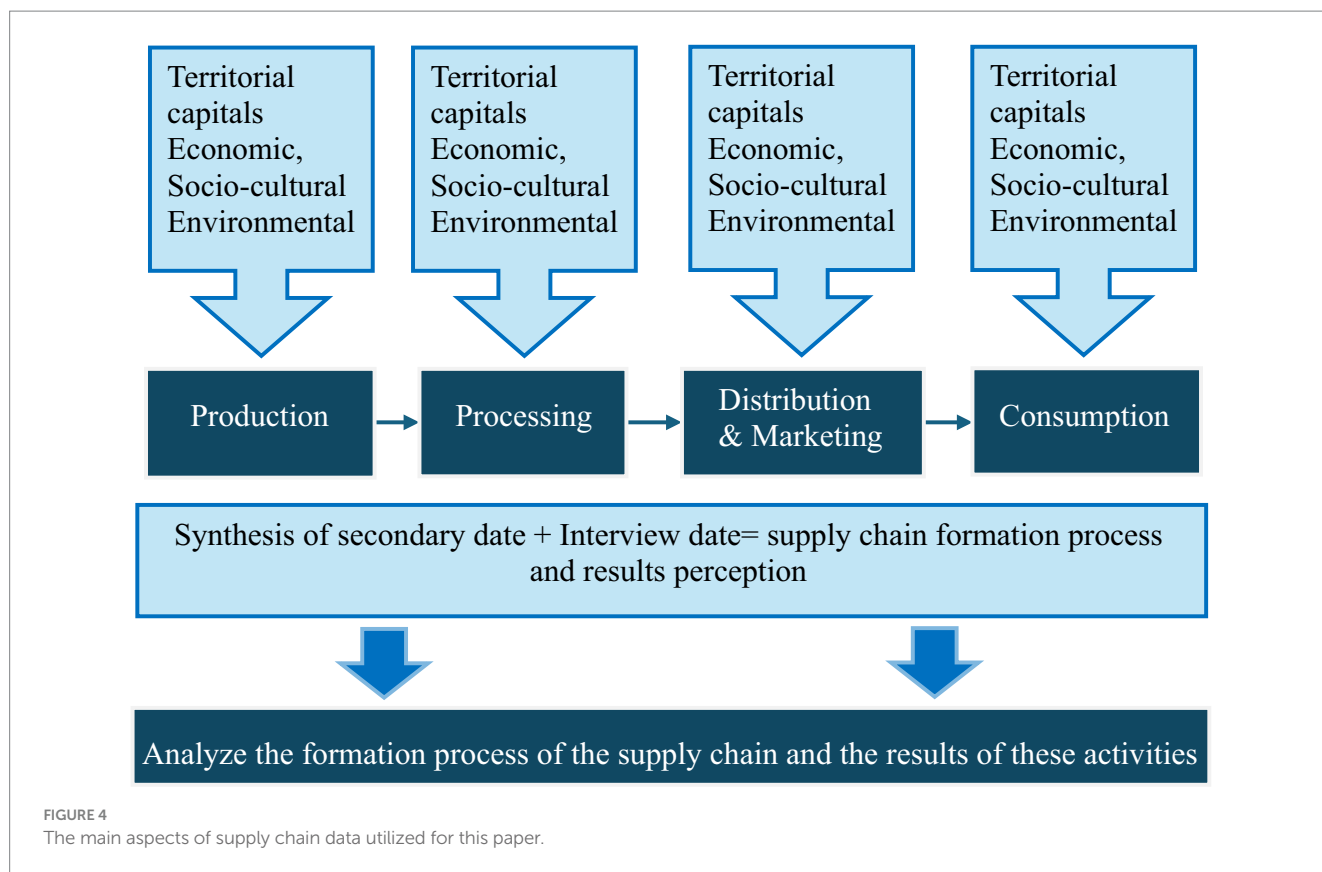
— Interviewee C, Kushima Aoi Farm Co., Ltd., Miyazaki Prefecture.

“Our export business is profitable now, but recent surges in fuel and fertiliser prices have raised production costs. Some foreign buyers worry about supply stability and are hesitant to make large-volume contracts.”

— Interviewee D, Nihon-Agri Inc., Aomori Prefecture.

In rural Japan, the integration of agricultural supply chains increasingly depends on actors whose motivations extend beyond short-term profit, reflecting a shift toward sustainable rural development. For instance, the yam supply chain managed by Obihiro-Kawanishi JA leveraged the agricultural cooperative network, strengthened regional branding, and obtained GI certification, thereby enhancing regional recognition. In contrast, emerging agri-SMEs such as Nihon-agri and the Neighborhood built export-oriented supply chains by adopting digital sorting technologies, diversified aggregation models, and interregional collaboration strategies.

These cases indicate that the marketisation of traditional cultivation knowledge, farmer-to-farmer information exchange, and shared infrastructure is becoming a viable pathway to stabilise farm incomes and enhance territorial economic outcomes. Moreover, returnee entrepreneurs and urban-to-rural migrants are emerging as key bridges linking local agriculture to global markets. Their performance is typically evaluated through the lens of long-term development and community well-being, rather than solely on conventional economic indicators.



4.1.2 Types of perceived economic outcomes

In terms of overall economic outcomes, the cases highlighted wage income, business profits, and employment growth as the primary results achieved through supply chain integration (Figure 5).

When various segments of the supply chain—from production and processing/sorting to distribution and sales—were effectively integrated, as observed in the cases of the Neighborhood (Miyazaki City), Nihon-agri (Aomori Prefecture), and the Aoi Farm (Kushima City), significant economic gains were realised. These enterprises captured key value-added stages by adopting diverse aggregation models, establishing in-house sorting facilities, and directly managing exports (Figures 6–8). Such integration not only enhanced product value and logistics efficiency but also increased the capacity of local economic actors to invest and innovate, thereby generating a virtuous cycle.

In some cases, increased profitability and wages incentivised reinvestment into upstream production and processing activities, leading to the accumulation of rural infrastructure and human capital. For example, in the supply chain development of the Neighborhood and the Aoi Farm, improvements in physical infrastructure, farm expansion, and the introduction of new processed products were directly supported by such economic returns. In another case, Yuzuoukoku in Kochi Prefecture strategically combined yuzu exports with cultural tourism and local experiences to enhance regional brand visibility. This parallel development of non-agricultural sectors also indirectly provided additional revenue for the local product.

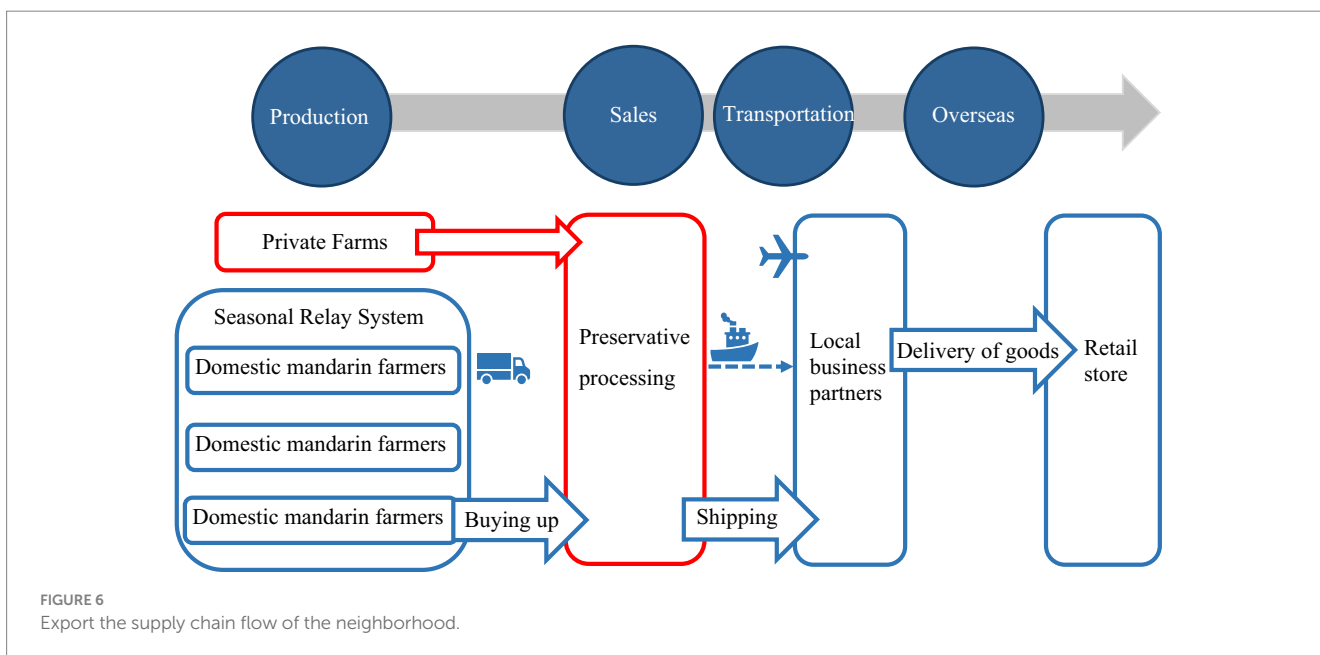
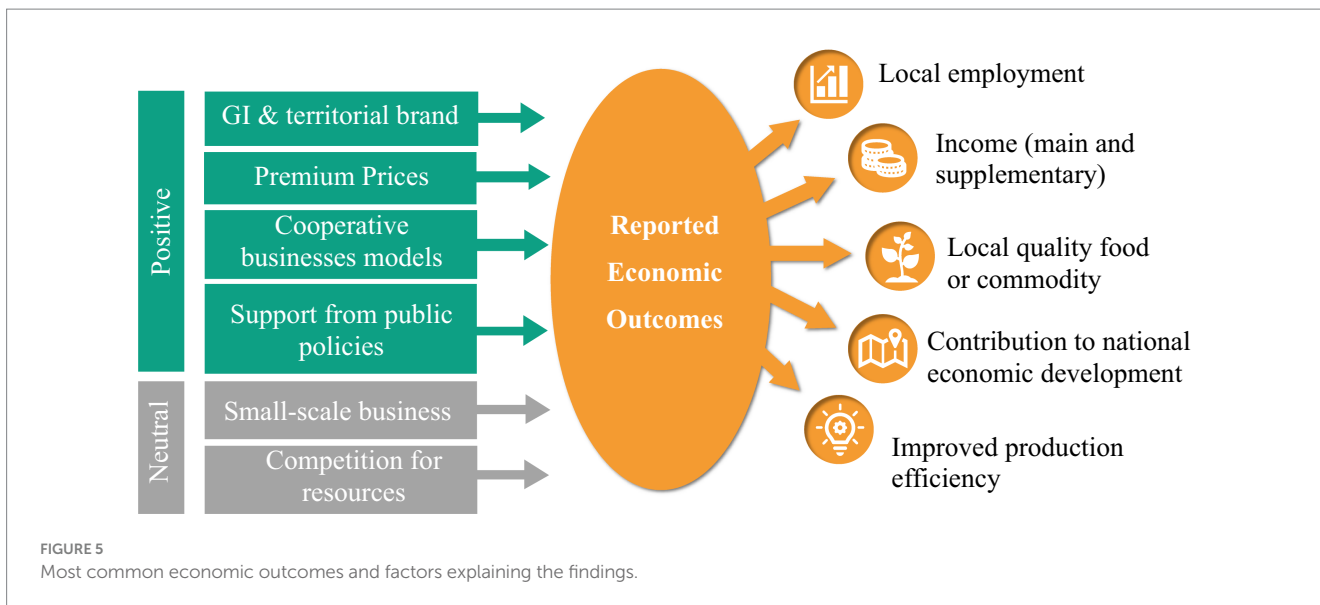
Moreover, some stakeholders reported that their participation in supply chains not only contributed to local economic growth

but also generated broader fiscal benefits through increased tax revenues at regional and national levels. Notable examples include Yuzuoukoku and Obihiro-Kawanishi JA, where the export of regionally branded agricultural products enhanced both farm-level income and local government revenue. However, the sustainability of these supply chains—especially those involving mountainous production areas—relies heavily on public support schemes, such as agricultural export subsidies and regional revitalisation policies.

As seen in Yuzuoukoku and the Neighborhood, although these products performed well in export markets, they often served as supplementary or seasonal income streams for local farmers rather than primary sources of livelihood. For farmers, such additional income is often used to cross-subsidise other agricultural or household operations, producing broader positive effects on the regional economy.

4.1.3 Factors explaining perceived economic outcomes

Japan's GI Protection System, symbolising both product quality and territorial identity, have emerged as a critical mechanism for enhancing economic performance in several cases. GI-certified products such as yuzu from Kochi Prefecture, Yam from Hokkaido and Apples from Aomori have all reported positive financial outcomes. Some enterprises attribute this phenomenon to the brand credibility and market positioning associated with GI certification. This system also institutionalises the connection between product origin and local resource systems. In specific contexts, such as the Aomori apple case, even amid intense international competition and fluctuating consumer

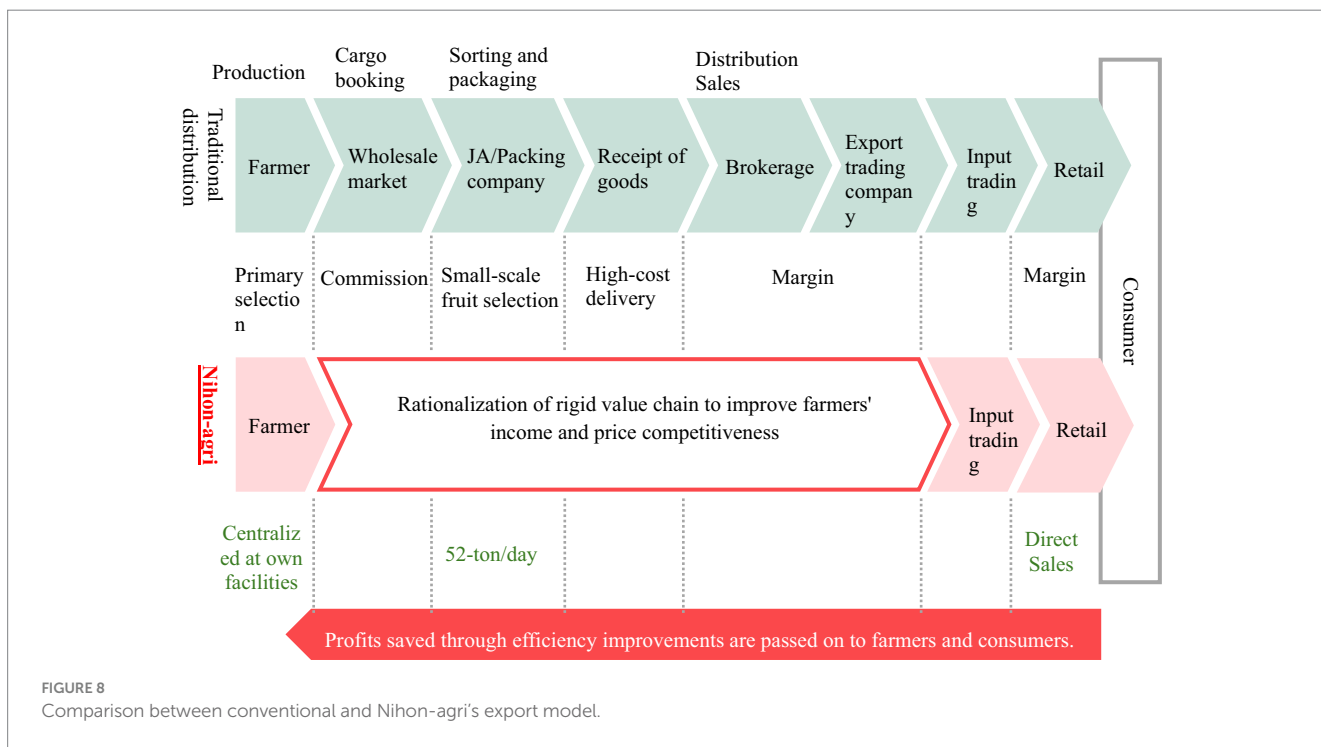
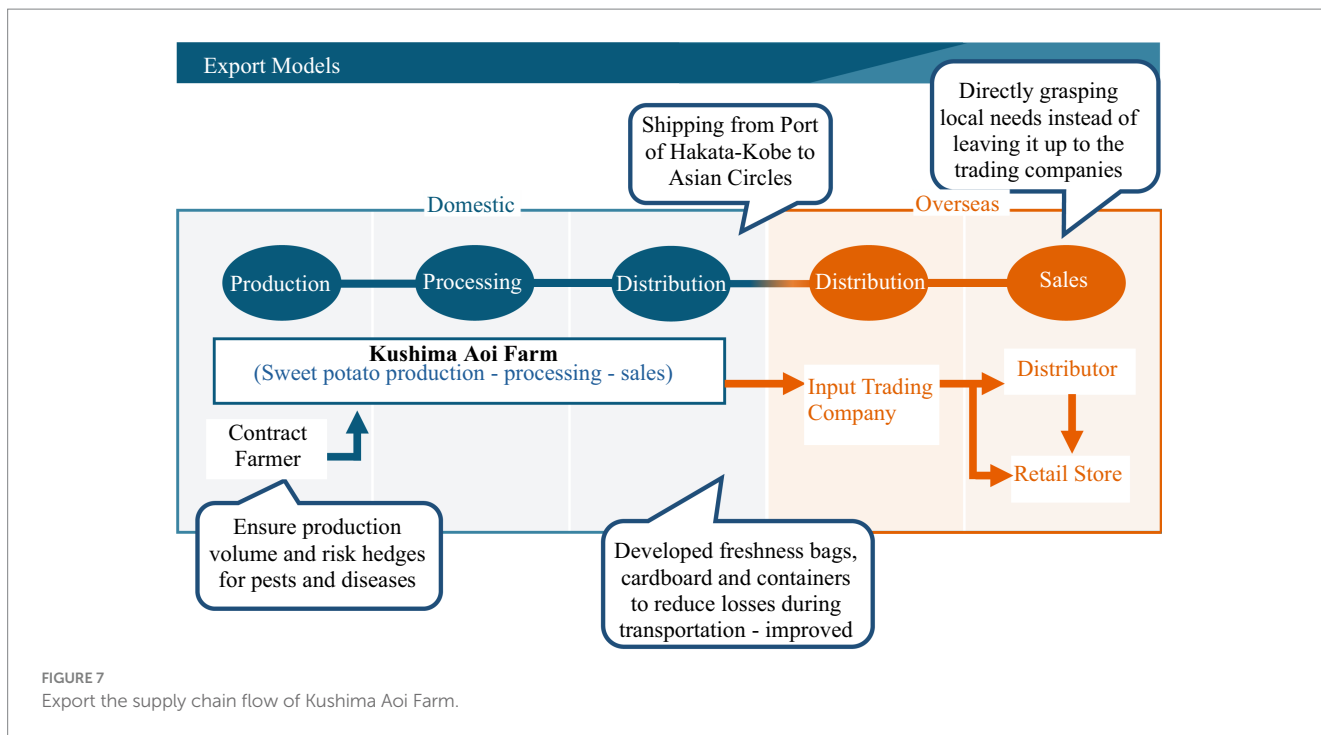


demand, the supply chain demonstrated notable economic resilience, suggesting that GI certification may serve as a risk-mitigation tool. However, several stakeholders noted that GI certification tends to be more effective within the Japanese domestic market than overseas, where recognition remains limited.

In addition, various export regulations—such as phytosanitary requirements and pesticide use standards—are significant factors affecting economic outcomes. While these regulations help position Japanese agri-food products in high-end niche markets and enhance their value-added potential, they also restrict production and processing flexibility and increase operational costs. In most cases, supply chains are led by small to medium-sized agri-enterprises, with only a few exceptions—such as the yam-exporting Obihiro-Kawanishi JA—operating under a cooperative model. Across all cases studied, cooperative networks or formalised collaboration

structures were identified as critical to improving economic performance. Given the vulnerability of small- and medium-sized producers to weather-related risks, concerns about supply stability were widespread. In response, farmer-led collaboration networks have emerged as practical solutions. For instance, the ‘Seasonal Relay System’ (Figures 9, 10) implemented by the Neighborhood leverages Japan’s geographically elongated terrain and staggered harvest times to aggregate crops across regions and stabilise supply. Overall, cooperation is seen as a viable strategy for small-scale producers to overcome diseconomies of scale and enhance their competitiveness.

These findings indicate that interactions among different business systems within the supply chain play a decisive role in shaping economic outcomes. These interactions were diverse and complex, sometimes resulting in unintended negative consequences. For example, in the case of Aoi Farm’s sweet

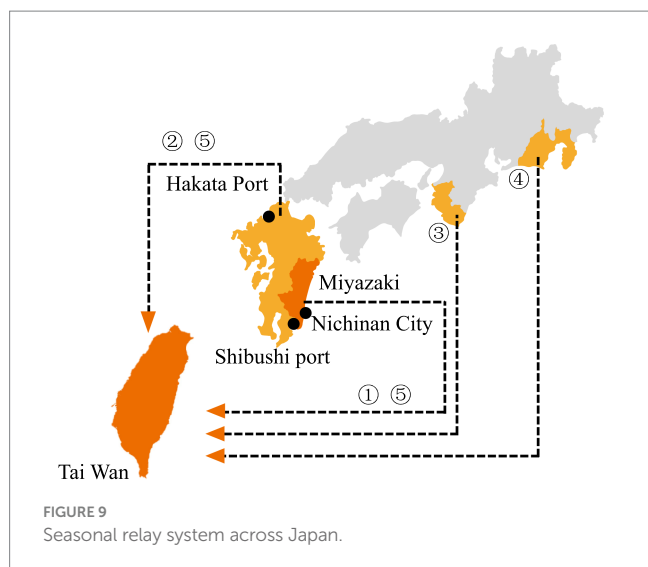


potato exports from Miyazaki Prefecture, growing overseas demand outpaced local supply, prompting the inclusion of non-local (albeit still domestic) inputs, raising concerns about threats to regional branding. In regions with underdeveloped export infrastructure, competition for shared logistics or market access was also reported. These examples suggest that while integrated supply chains can generate significant economic synergies, achieving sustainable rural growth will ultimately

depend on the development of effective supply chain governance mechanisms.

4.2 Socio-cultural outcomes

The sustainable supply chains proposed in this study not only address conventional economic development but also incorporate



broader aspects related to socio-cultural progress and human well-being. These include collaborative mechanisms, traditional cultural practices, human capital, and the equitable distribution of opportunities. The cultivation of future agricultural successors and the mitigation of an ageing farming population emerged as the most prominent socio-cultural outcomes reported. These outcomes are closely linked to enhancing the attractiveness of rural areas and promoting sustainable rural development (Figure 11).

4.2.1 Perceived changes in the territorial social capital base

In most cases, respondents perceived that integrating export-oriented supply chains contributed to positive socio-cultural outcomes, and none reported negative impacts on regional socio-cultural development. However, in some cases—such as Nihon-agri—where market demand, consumer preferences, and sales targets served as the primary drivers, the resulting socio-cultural outcomes were relatively limited.

“Working together for export has strengthened relationships among local farmers. We communicate more frequently and share information that used to stay within each farm.”

— Interviewee E, Neighborhood Co., Ltd., Miyazaki Prefecture.

“Before starting exports, farmers here mainly thought about their own yields. Now, they feel proud that their produce represents the region. The idea of ‘selling the region together’ has become stronger.”

— Interviewee F, Yuzuoukoku Co, Kochi Prefecture.

4.2.2 Types of perceived social outcomes

The integration of many supply chains is closely linked to the enhancement of human capital, which is regarded as a major socio-cultural outcome. In several cases examined in this study, such as the Neighborhood in Miyazaki Prefecture and Nihon-agri in Aomori Prefecture, supply chains fostered agricultural successors by attracting young people to participate at various stages of agricultural

production, thereby alleviating the pressure of rural population ageing. Moreover, the Aoi Farm in the Miyazaki Prefecture enhanced the attractiveness of agrarian careers to young people by integrating youth internships with collaborations between experienced farmers and university-based research and development. Through supply chain integration, these efforts have not only improved economic performance but also supported the renewal of rural labour forces and the sustainable development of rural communities.

During supply chain construction, intra- and interregional cooperation and trust are key drivers of integration. For example, the Neighborhood in Miyazaki Prefecture exemplified interregional collaboration. This company adopted a cooperative model distinct from traditional agricultural cooperatives, alleviating farmers’ burden by providing comprehensive technical and logistical support throughout cultivation and shipping, and offering higher purchase prices than conventional cooperatives. These practices demonstrate a high degree of coordination and trust among agricultural producers. In addition, Nihon-agri maintains farmer trust and cooperation by sharing information, resources, and infrastructure. These efforts have not only improved supply chain efficiency but also laid the foundation for integrating regional resources and rural revitalisation.

However, such virtuous interactions are not universally observed. In the preliminary investigation of this study, an emerging citrus export case from the Mie Prefecture in Japan reported a loss rate of up to 42.8% due to inadequate post-harvest preservation measures for fresh citrus and overly cumbersome, time-consuming quarantine procedures at the export destination. Although demand in the Thai export market remained relatively stable, the high loss rate and stringent customs requirements discouraged producers, resulting in the underutilisation of local resource potential and the collection capacity of the leading exporter, the Mie Prefecture JA, losing the trust of farmers. This outcome indicates that trust-based cooperative mechanisms are fundamental to achieving social sustainability in export-oriented agricultural supply chains.

Across the cases examined in this study, the performance of different supply chain stages varied in terms of accessibility and local ownership. In most cases, such as the yam supply chain of Obihiro-Kawanishi JA and the apple export network in Aomori, high levels of local ownership were observed at the production and processing stages. Farmers and cooperatives retained decision-making power and jointly managed infrastructure. However, at the distribution and marketing stages—particularly at the consumption stage—local control diminished significantly, as distributors and overseas retailers typically dominated these stages. Nevertheless, many respondents noted that the production, sorting, and processing stages offered accessible employment opportunities for local residents, often without requiring advanced education. This suggests that export-oriented supply chains, when embedded in local cooperative networks, can serve as a robust model for endogenous regional development.

4.2.3 Factors explaining perceived social outcomes

In the supply chains examined in this study, a strong governance structure based on collaborative coordination emerged as a key factor influencing socio-cultural outcomes. The cases of Obihiro-Kawanishi JA and Yuzuoukoku demonstrated that relying on agricultural

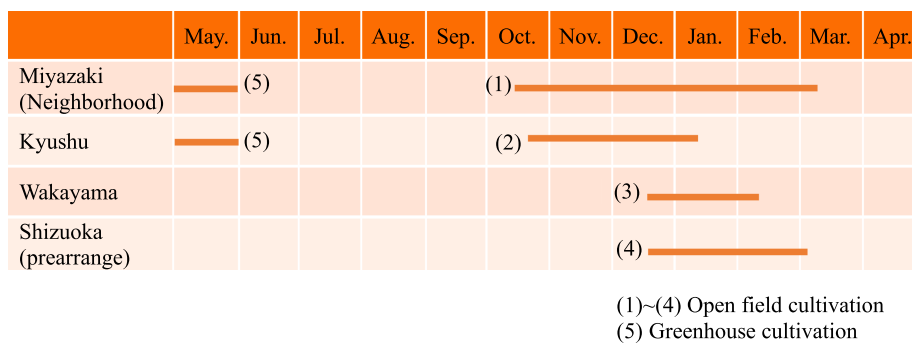


FIGURE 10 Seasonal relay system harvest time.

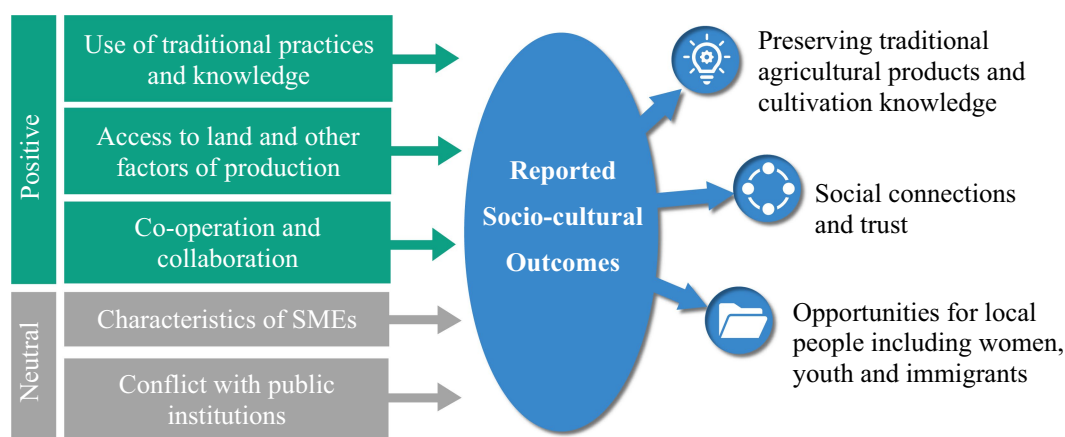


FIGURE 11 Most common socio-cultural outcomes and factors explaining the findings.

cooperatives or well-established regional brands not only improved the operational efficiency of export-oriented supply chains but also strengthened the sense of place, preserving traditional cultivation knowledge and practices, and enhancing regional cohesion. By contrast, market-driven supply chains led by SMEs, such as Nihon-agri's apple export supply chain, tended to weaken cultural continuity and intergenerational knowledge transfer, yielding limited socio-cultural benefits. This pattern suggests that socio-cultural outcomes are not solely determined by the firm's level of internationalisation or market reach but rather depend on the extent to which supply chain governance incorporates collaborative coordination and regional brand development into its operations and management.

In this study, cases led by Nihon-agri, the Neighborhood, and the Aoi Farm SMEs demonstrated flexible responsiveness and a strong awareness of brand development, yet achieved limited socio-cultural outcomes. Compared to supply chains led by cooperatives and large trading companies, such as Obihiro-Kawanishi JA in Hokkaido and Yuzuoukoku, these SMEs were constrained by limited resources, relatively closed management structures, and weaker cooperative networks. Namely, they found it more challenging to incorporate the preservation of traditional cultivation knowledge, practices, and regional cohesion into their business objectives. Although SMEs

possess advantages such as flexibility, innovation, and rapid decision-making, which facilitate their expansion into overseas markets, the lack of a robust export cooperation mechanism has limited the realisation of socio-cultural outcomes. This suggests that the socio-cultural outcomes of export-oriented supply chains are closely linked to how SMEs integrate regional resources and build cooperative networks.

Furthermore, this study finds that the weak socio-cultural outcomes of export-oriented supply chains led by agri-SMEs stem partly from the lack of, or limited access to, support from local administrative systems. For example, the Neighborhood and the Aoi Farm adopted market-driven approaches, collecting produce across regions and bypassing local agricultural cooperatives to export directly, thereby disrupting the traditional public-sector-led export model and marginalising them by local public institutions, which weakened their connections with local communities. In contrast, cooperative models such as those of Obihiro-Kawanishi JA and Yuzuoukoku integrated public authorities, farmers, and logistics resources, maintaining local identity and collaboration, and thereby achieving higher socio-cultural value. This suggests that the degree of alignment with local governance structures is a critical factor influencing the socio-cultural outcomes of supply chains.

4.3 Environmental outcomes

Sustainability requires human development to remain within the limits of planetary resources and the harmonious coexistence with nature. Therefore, the analysis of SSCM needs to focus on how supply chain construction—such as the utilisation of natural and agricultural resources and the reduction of waste and greenhouse gas emissions—can contribute to environmental outcomes. The environmental outcomes of export-oriented supply chains included encouraging eco-friendly agrarian practices, reducing losses and waste and enhancing resilience to weather and climate change (Figure 12).

4.3.1 Perceived changes in the territorial environmental capital base

Overall, compared to economic and socio-cultural perspectives, the environmental outcomes of supply chain integration remained relatively limited, although most cases reported a positive trend in ecological benefits. In some cases, such as the yam supply chain of Obihiro-Kawanishi JA in Hokkaido, traditional cultivation methods and crop rotation practices contributed to improved soil health and biodiversity. Other SME-led supply chains reduced pesticide and fertiliser use in response to stringent pesticide residue standards in export markets, with some crops shifting to organic cultivation for European markets, thereby indirectly improving regional environmental conditions. Additionally, some cases reduced food waste and losses by optimising logistics, shortening transportation times, and streamlining procedures.

“Because we export to Europe, we had to meet stricter pesticide residue standards. This pushed us to reduce chemical inputs and gradually move toward more organic cultivation practices.”

— Interviewee G, Yuzuoukoku Co, Kochi Prefecture.

“Our crop rotation system helps maintain soil fertility and keeps pests under control naturally. It also brings back small animals and insects that disappeared when we used more chemicals before.”

— Interviewee H, Obihiro-Kawanishi JA, Hokkaido Prefecture.

“A major challenge in maritime transport was the occurrence of mould and spoilage caused by condensation. With conventional packaging, it was difficult to maintain freshness during long-haul shipping, resulting in an average wastage rate of around 30%, and in some cases exceeding 60%. To address this issue, we consulted a packaging materials manufacturer and jointly developed and commercialised a dedicated package designed to prevent condensation. Although the unit cost of the new packaging was five to six times higher than that of the conventional option, it reduced the wastage rate to approximately 10%.”

— Interviewee I, Aoi Farm Co., Ltd., Miyazaki Prefecture.

4.3.2 Types of perceived environmental outcomes

Respondents indicated that the construction of export-oriented supply chains helped raise local awareness of environmentally friendly cultivation practices. As export destination markets imposed increasingly stringent standards on pesticide residues, soil management, and quarantine, more participating farmers were encouraged to reduce pesticide use and adopt practices such as crop rotation and organic farming. For example, the yam supply chain of Obihiro-Kawanishi JA implemented a unified pest and disease management system and long-cycle crop rotation, which not only controlled plant diseases but also raised farmer awareness of soil conservation. In addition, market-oriented SMEs such as Aoi Farm and Neighborhood also shifted toward more ecologically conscious farming practices, driven by the high standards of export markets. Yuzuoukoku, targeting the European market, established dedicated orchards for organic yuzu cultivation. The approaches to fostering this awareness varied, and although significant environmental outcomes have not yet materialised in the short term, they lay an essential foundation for sustainable agricultural development.

Additionally, three enterprises or cooperatives reported environmental outcomes related to waste reduction. Obihiro-Kawanishi JA, the Aoi Farm, and Nihon-agri effectively reduced food waste by exporting agricultural products that did not meet domestic market standards due to irregular shapes or non-standard sizes. For example, Obihiro-Kawanishi JA exported oversized yam roots (larger than 2 L) from Hokkaido to Taiwan and the United

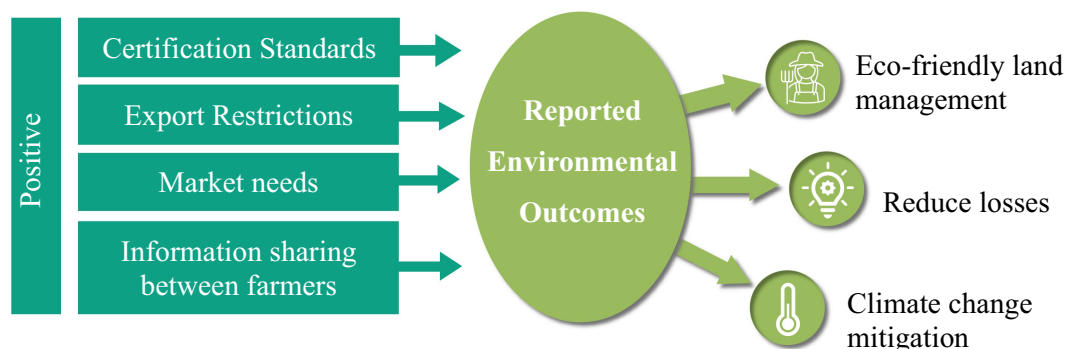


FIGURE 12 Most common environmental outcomes and factors explaining the findings.

States in response to market demand. Similarly, the Aoi Farm, recognising the Southeast Asian consumer habit of steaming sweet potatoes with rice in rice cookers, exported small-sized sweet potatoes—rejected by the Japanese domestic market—to Southeast Asia. By catering to overseas consumer preferences, these practices improved resource utilisation.

Although export-oriented supply chains tend to become decoupled from local resources at the distribution and consumption stages, respondents in this study indicated that the construction of such supply chains generally improved farmer capacity to cope with climate change. To address the uncertainties posed by climate change and fluctuations in market demand, SME supply chain leaders actively shared information. They collaborated with farmers to stabilise supply, thereby mitigating the impact of climatic anomalies on yield and quality. However, two enterprises reported that in the later stages of the supply chain—particularly during distribution and consumption outside rural areas—an increased reliance on packaging materials and long-distance transportation heightened greenhouse gas emissions and energy consumption, thereby diminishing the overall environmental benefits.

4.3.3 Factors explaining perceived environmental outcomes

Interview data suggested that environmental outcomes were closely linked to the growth of market demand. SMEs, such as the Neighborhood and Nihon-agri, responded to expanding overseas market demand, reduced pesticide use, and disease transmission by standardising contract-farmer management and improving post-harvest preservation techniques, thereby enhancing ecosystem health and protecting soils. Moreover, demand for healthy, safe, and high-quality Japanese agricultural products has been increasing annually in overseas markets, particularly in Southeast Asia. This growing demand has driven SMEs to align with consumer preferences, optimise operational systems, upgrade processing and sorting equipment, and improve logistics efficiency, thereby facilitating their transition toward greater environmental friendliness. However, the interview data also indicated that, in the absence of effective governance and oversight, excessive market-driven practices aimed solely at meeting demand may create new environmental pressures. Therefore, future efforts should seek to balance market responsiveness with stronger guidance on environmental sustainability.

The complexity of supply chain integration may partly explain the limited environmental outcomes observed in some cases. For example, in the citrus supply chain of the Neighborhood and the sweet potato supply chain of the Aoi Farm, agricultural products from diverse regions and cultivation systems were integrated into unified, export-oriented supply chains. Although this integration enhanced supply stability and market competitiveness, it also amplified adverse environmental effects associated with non-local production, such as increased carbon emissions from longer transportation distances and greater environmental management challenges arising from heterogeneous farming practices and soil conditions. These findings, combined with the positive outcomes described earlier, highlight the context-dependent nature of environmental impacts from supply chain integration. Overall, like socio-cultural outcomes, environmental outcomes showed strong context dependence and heterogeneity, making it challenging to derive universal patterns across all cases.

5 Discussion

This study developed and tentatively applied an analytical framework derived from a supply chain analysis to explore pathways toward more sustainable rural development. The discussion is organised into three parts. Firstly, it examines the characteristics of export-oriented supply chains in the cases studied. Secondly, it considers how this approach offers a neo-endogenous perspective on regional development in Japan's rural areas. Thirdly, it reflects on the limitations of this study and outlines directions for future research.

5.1 Key characteristics of export-oriented supply chains

The findings from the five cases suggested that export-oriented supply chains led by agri-SMEs in rural Japan were not merely instruments to open overseas sales channels. Instead, in the contexts examined, they tended to function as distinctive value-adding systems for agricultural products, shaped jointly by external market demand and internal regional conditions. The main features of these supply chains are described below.

Firstly, evidence from the five cases suggested that the development of export-oriented supply chains in rural Japan was not primarily driven by domestic oversupply, as is often assumed, but rather by differentiated demand in specific overseas markets. Stakeholders along the chain adjusted product attributes—such as size, sweetness, storage methods, and processing forms—in line with the preferences of particular foreign markets. For instance, in the cases examined in this study, consumers in Southeast Asia tended to prefer smaller sweet potatoes, whereas the Taiwanese market was reported to favour larger yam. After recognising these opportunities, both case firms chose to cater to overseas preferences by exporting off-grade produce that did not meet Japanese domestic size standards, thereby improving their profitability. For example, 4 L-size yam sells domestically for about 2,700 yen/10 kg box, while exports to Taiwan command a premium of roughly 100–200 yen/box, bringing the price close to that of the mainstream 2 L grade in Japan (around 3,000 yen/box). In terms of returns, company data showed that the gross income per unit area for yam increased from an average of 562,000 yen/10a before exports (1971–1998) to 774,000 yen/10a after exports (1999–2022), representing an increase of approximately 30% (Table 4).

Furthermore, this 'overseas-demand-oriented adjustment of production' was associated with different socio-cultural and environmental effects across supply chains led by other types of organisations. In cooperative-led chains (e.g., Obihiro-Kawanishi JA), export activities were employed to help stabilise domestic prices for yam in Japan, and as part of efforts to maintain relatively stable local cropping systems—such as rotations among potatoes, beans and yam—which are regarded as essential for soil conservation and the preservation of agricultural diversity.

By contrast, in the case of the Aoi Farm, SME-led supply chains influenced environmental and socio-cultural outcomes more indirectly through technological innovation and product differentiation. For example, in its sweet potato export business, the Aoi Farm promoted cultivation improvements and upgrades to storage technologies tailored to overseas markets, developing techniques to produce small-sized sweet potatoes for export and

TABLE 4 Yam 10a income trends.

Year	Category	Main initiatives	Income from 10a (1,000 yen/10a)
1971–1984	Production area establishment period	The Kawanishi Sosai Production Association was established, establishing the first production organisation.	513
1985–1991	Production expansion period	The Yam Management Council was established, a wide-area joint sales system was launched, and the planting area tripled.	502
1992–1998	Area establishment period	Beppu facility improvements and a year-round supply system established.	622
1999–2006	Export initiation period	Exports to Taiwan and other countries begin.	740
2007–2022	Export expansion period	Exports to the U.S. and Singapore begin.	807

applying double-curing preservation. According to company records, this reduced the spoilage rate from an average of 30 to 10%. Although this model involved fewer farmers than cooperative systems, it had lower storage losses. It may have reduced the use of chemical additives for preservation, thereby indirectly generating ecological benefits. In addition, the firm took partner farmers to overseas markets so they could see their own sweet potatoes being well received abroad; interviewees reported that this experience fostered pride and functions as a motivational mechanism. Over the same period, the company's operating scale expanded from a 30-ha self-managed farm before exports to a 250-ha production base that includes partner farmers across Japan. Against the backdrop of an ageing producer population and young people leaving agriculture, such socio-cultural benefits may help facilitate the diffusion of techniques, varietal upgrading, and brand value enhancement, thereby potentially contributing to more sustainable development trajectories in the rural contexts concerned.

Secondly, in the cases examined, the development of these supply chains appeared to depend on cooperative networks that supported production and shared risks. Taking Obihiro-Kawanishi JA as an example, this system not only coordinated production across regions but also used exports to stabilise domestic prices during periods of yield fluctuation. This institutional arrangement was perceived to have clear economic functions: it helped absorb surplus produce generated in bumper-harvest years and strengthened farmer bargaining power through unified storage, grading, and sales systems.

In contrast, in the SME-led supply chains examined, although overall coverage was smaller, they tended to build tighter, more

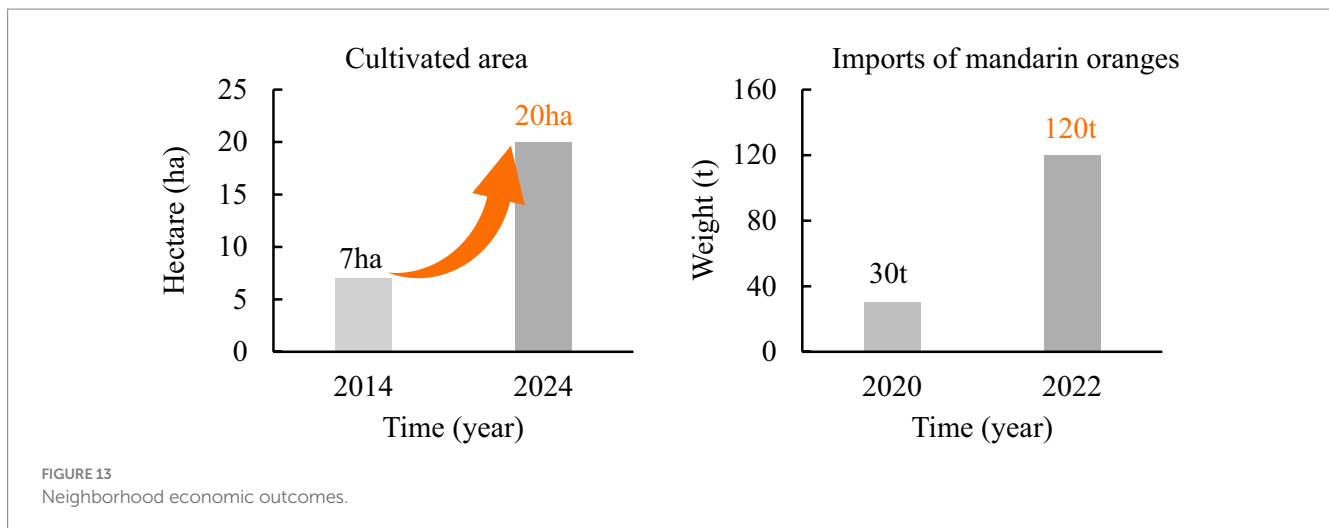
targeted cooperation networks. For instance, the Neighborhood and its partner farmers established a Seasonal relay system, a network that worked together to address export barriers such as insufficient supply volumes, pesticide residue controls, and quarantine requirements, thereby forming what can be described as an 'intensive cooperation model' based on technical support and shared market information. Through cultivation guidance, joint improvements in storage technology, and the adoption of standardised export criteria, this type of network can enable small-scale farmers to access higher-value-added markets.

Although the Miyazaki Prefecture, where the Neighborhood is located, is not a major mikan-producing region, exports began in 2020, and buyers required shipments of around 6 tonnes per week. Because such volumes could not be secured by a small farm like the Neighborhood alone, the firm adopted an entirely new approach. It stopped supplying the wholesale markets it had worked with for decades and instead consolidated mandarins produced by neighbouring growers to ensure export volumes. To maintain export-grade quality, the Neighborhood shared its accumulated know-how in production, storage, and transport with other producers and undertook sorting and selection in-house. In 2024, the firm expanded its orchards, planting an additional 5,400 saplings. However, it had maintained about 7 ha over the past two decades, its cultivated area has now expanded to roughly 20 ha and continues to grow.

Furthermore, by mobilising producers nationwide and implementing a cross-prefecture relay system, the Neighborhood built a structure that enabled mandarins to be exported over longer periods by connecting the peak-quality seasons of different regions. At present, the firm trades with about 30 producers in Fukuoka, Kumamoto, Nagasaki, and Saga, and since this year, it has also involved growers in Wakayama and Shizuoka, where harvesting occurs slightly later than in Kyushu, thereby establishing a seasonal relay system for exports. This has extended the export season and enabled mandarins to be shipped at their best taste in each period. Export volumes increased from 30 tonnes in 2020 to 120 tonnes in 2024 (Figure 13). Owing to these efforts over the past five years, the Neighborhood has attracted national-level attention and was awarded the MAFF Export and International Affairs Bureau Director-General's Prize in the 2024 fiscal year. While based on a single firm, this case suggests that finely tuned cooperation networks can enhance the market value of products and may help small farmers lacking scale advantages to access higher-income opportunities.

Therefore, evidence from the five cases suggests that, whether a supply chain is led by a cooperative or by an agri-SME, its cooperation network can function not only as a channel for technical collaboration but also as a mechanism for sharing risks and enhancing value. By working together, these networks may lower some of the barriers that agri-SMEs and smallholders face in accessing international markets, thereby creating opportunities for Japan's dispersed and small-scale farmers to participate in export activities through organisation, knowledge sharing, and pooled resources.

Finally, in the cases examined, agri-SMEs appear to play an important coordinating role between regional economies and international markets in processes of sustainable rural development. For example, the case firms in this study—the Neighborhood, the Aoi Farm, and Nihon-agri—have sought to open overseas markets by moving swiftly, creating differentiated products and employing staff with expertise in exporting, international logistics, and overseas



marketing. According to interviews and company data, these activities have been associated with increases in local employment and improvements in farmer incomes. These firms do not compete primarily based on regional brand fame or mass export volumes. Instead, they rely on their agility, product differentiation, and market insight. Even in rural areas where business resources are limited, they have been able to organise and engage in exports of high-value-added agricultural products.

Figure 14 shows Japan's agricultural export performance from 2002 to 2023. Based on the export trend, 2013 appeared to mark a turning point. The chart indicates that between 2002 and 2012 Japan's agricultural export value hovered for a long time roughly within the 20–30 million yen range, fluctuating sideways overall. From 2013 onwards, however, exports moved into a steeper upward trajectory, reaching nearly 93 million yen by 2023, roughly doubling over the course of a decade. This inflexion broadly coincided with the government's launch of the 'country-by-country and product-by-product export strategy' in 2013—which designated priority items and target markets—and with the further policy shift in 2020 toward 'strengthening production for overseas markets.' Taken together, these policy changes supported a growing emphasis on exports, thereby framing exports to external markets as a potential new growth engine for Japanese agriculture rather than a mere ancillary option.

Nevertheless, the scale and requirements of export expansion often exceed what individual farm households can bear. Entering overseas markets entails substantial thresholds that individual farmers often cannot overcome on their own. Against this backdrop, the corporatisation of agricultural management has become an organisational foundation for export growth. According to the 2023 Survey on the Movement of Agricultural Structure, the total number of agricultural management entities nationwide was 929,400, a year-on-year decrease of 4.7%. Of these, individual management entities totalled 888,700, down 5.0% from the previous year. By contrast, group management entities totalled 40,700, an increase of 1.5%, while incorporated management entities reached 33,000, rising by 2.5% each year. Incorporated entities thus accounted for about 81% of all group management entities (Table 5).

In other words, even as the overall number of management entities continued to decline, corporatised farms grew against the trend. They appeared to become important new agricultural bearers,

suggesting a gradual shift in Japanese agriculture from predominantly 'dispersed producers' toward more 'enterprise-based managerial actors.'

Exporting agricultural products does not require a 'point-like supply' from individual farmers, but rather a stable and long-term 'systemic supply' that can continually align with overseas demand. Through corporatised management, agri-SMEs can develop and mobilise three key capabilities: (1) stable supply and standardised production; (2) supply chain integration and more professionalised responses to foreign-trade requirements; and (3) networked collaboration and differentiated market positioning. As suggested by the cases examined in this study and related literature, export systems in which agri-SMEs operate as hubs may generate positive effects for sustainable rural development. Economically, export growth can bring higher added value to rural areas, enabling localities to become more than mere 'production sites' and to begin to develop regional industrial systems encompassing processing, cold-chain logistics, packaging, and employment. Socially, agri-SMEs often create jobs beyond primary production—such as quality control, trade, marketing, IT, and related functions—which may help attract young people and in-migrants, increase occupational diversity and enhance the possibility of demographic recovery in rural communities. Environmentally, overseas standards and certification requirements can exert pressure for greener production and traceable management, potentially encouraging a shift in local agriculture from an exclusive focus on 'expanding quantity' toward strengthening 'quality-based competitiveness.' Taken together, these observations indicate that the construction of export-oriented supply chains can constitute a possible pathway to advance sustainable development in rural areas. However, the magnitude and distribution of these effects are likely to remain highly context-dependent.

Furthermore, in the cases examined, agri-SMEs appear to act not only as executors of agricultural exports but also as essential actors in building export competitiveness and promoting more sustainable forms of rural development. Their business models suggest that the internationalisation of Japanese agri-SMEs need not rely solely on scaling up production; instead, by leveraging relatively efficient cooperation networks, attracting specialised human resources and pursuing differentiated market positioning, some small-scale agricultural operations have begun to evolve into regionally embedded

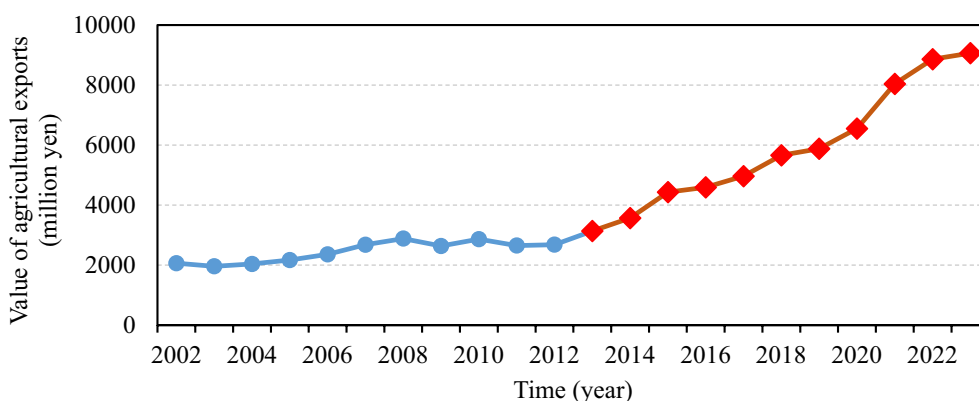


FIGURE 14 Comparison of Japan's agricultural export performance from 2002 to 2023.

TABLE 5 Number of agricultural management entities in Japan nationwide.

Category	Agricultural management entity ① + ②	Individually operated farms ①	Unit: 10 ³ management entities	
			Group-managed farms ②	
			Corporate farms	Others
2022	975.1	935.0	32.2	7.9
2023	929.4	888.7	33.0	7.7
Percentage change (%)	▽4.7	▽5.0	2.5	▽2.5

industrial systems that exhibit elements of global competitiveness and may contribute to both economic and, to a more limited extent, demographic revitalisation.

5.2 Sustainable rural development

This study uses a comparative multi-case analysis to explore how Japanese agri-SMEs build supply chains and participate in international markets, thereby offering an exploratory contribution to the literature at the intersection of agri-food supply chains, SME internationalisation, and sustainable rural development. Building on the characteristics outlined in Section 5.1, this subsection discusses how these supply chain configurations relate to broader debates on sustainable rural development in Japan. While previous research has predominantly focused on large corporations, the case evidence presented here suggests that some Japanese agri-SMEs can also attain competitiveness in global markets by leveraging flexible business strategies and community-embedded cooperative networks, often without relying directly on large enterprises. In doing so, they may be able to turn the characteristics of small-scale operations and local embeddedness into assets that align export-oriented growth with elements of rural revitalisation. Given the small number of relatively successful cases and the qualitative design, however, the findings should be regarded as illustrative and context-specific rather than definitive or generalisable.

Against the backdrop of an ageing agricultural workforce, rural Japan faces well-documented structural challenges, including shortages of successors, labour constraints, and widespread land

abandonment (Ministry of Agriculture, Forestry and Fisheries, 2025a). In response, the Japanese government has promoted policies framed as ‘efficiency-driven agriculture’, encouraging the large-scale consolidation of farming operations (Ministry of Agriculture, 2025). However, this model has often proved challenging to implement in mountainous areas, which account for approximately 40% of Japan’s farmland (excluding Hokkaido), where geographic and operational constraints limit the feasibility of large-scale farming. As a result, while continuing to foster large agribusinesses, the MAFF has increasingly emphasised the importance of agricultural diversity, particularly by incorporating small-scale farming models (Ministry of Agriculture, Forestry and Fisheries, 2025). This shift can be broadly interpreted as consistent with the principles of neo-endogenous development, which place local actors at the centre and advocate for place-based strategies that draw on local natural, social, and cultural resources while engaging international markets to attract external resources for synergistic development (Greenberg et al., 2018). From this perspective, a ‘think globally, act locally’ approach may offer a potential pathway toward the sustainable development of rural regions.

The study further suggests that market-oriented business strategies may help SMEs to mitigate some of the constraints associated with their small scale and to develop more competitive, growth-oriented positions in their markets (Eckstein et al., 2015). Rather than simply “finding buyers,” these strategies require agri-SMEs to build organisational capabilities to coordinate production across regions and seasons, managing quality and safety standards, and sharing market information with partner farmers. In turn, such capabilities can support the stabilisation of agricultural supply,

strengthen trust with trading partners, and help secure access to export channels. This pattern, together with prior research indicating that firms increasingly derive a competitive advantage from extra-local trading relationships (Bennett and Smith, 2002), implies that policy assistance may be more effective when tailored to the relational, learning, and coordination needs of agri-SMEs themselves rather than designed solely around locality-based branding.

Moreover, across the five cases, supply chain integration led by agri-SMEs and cooperatives can be viewed as a socio-institutional mechanism that links economic, social, and environmental dimensions of rural development. Trust-based cooperation, long-term contracting, and joint standard-setting do not merely secure export volumes; they also create platforms to cultivate the next generation of farmers through training and internships, facilitate the diffusion of cultivation and storage techniques, and gradually internalise environmental standards originating in overseas markets. Practices such as reducing pesticide use, encouraging crop rotation and organic production, exporting off-grade produce to reduce waste, and optimising logistics to minimise losses all emerge within this framework of export-oriented coordination. Although the socio-cultural and environmental outcomes observed in these cases were generally less pronounced than the economic gains, the overall direction of change associated with supply chain integration appeared to be positive. Achieving more substantial socio-cultural and environmental outcomes, while maintaining economic performance, is likely to be important for sustainable rural development, highlighting the potential significance of effective SCM.

5.3 Limitations of the study

This study focused on how Japanese agri-SMEs can help rejuvenate regional economies through supply chain integration, but it has some limitations. First, the study primarily examined successful export cases that demonstrate growth and effective supply chain coordination. This sample bias restricts the generalisability of the findings, as unsuccessful or stagnating firms were excluded. Therefore, the findings should be interpreted as analytically generalisable insights into how and under what conditions export-oriented agri-SMEs can contribute to rural sustainability, rather than as claims about average firms. Transferability is most plausible in contexts that share crucial boundary conditions with this study's cases: rural Japan (or comparable institutional settings), small- and medium-sized agricultural firms, differentiated products requiring standardised production, grading, precooling/processing and cold-chain coordination, and the presence of dense cooperative networks (e.g., with local governments, JA organisations, logistics actors, and contract growers). Under these conditions, export markets can be leveraged through network efficiency, talent absorption and niche positioning without relying on scale expansion. In contrast, the insights may be less transferable to contexts dominated by scale-based commodity competition, weak cold-chain or certification infrastructure, or supply chains fully controlled by large trading companies where local SMEs have limited strategic autonomy. Future research should incorporate cases at different performance stages, including firms facing export stagnation or failure, to further test and refine the boundary conditions identified here.

Secondly, to systematically analyse these five distinct cases, the study emphasised on descriptive categorisation rather than the rich details of how each supply chain was constructed or the novel viewpoints expressed during the interviews. The analysis is based on the status of supply chains at the time of the study and does not assess how outcomes have changed over time. Overall, the approach is deductive, applied to the interpretation of qualitative data, and not focused on statistics. Therefore, the dataset is relatively limited in both sample size and depth. Although the study provides qualitative insights from 5 cases and 15 interviews, the evidence may not fully capture the diversity of Japan's agricultural export sector. Expanding the dataset through additional case studies, field surveys or quantitative performance indicators would enhance the robustness and representativeness of future analyses.

Finally, as this study is exploratory in nature, its findings should be interpreted as indicative rather than conclusive. While the analysis contributes to the theory of agri-SME development and rural economic policy, further quantitative research is required to verify the causal relationships between operational capacity.

6 Conclusion

This study proposes and illustrates a conceptual analysis framework, grounded in a socio-ecological systems perspective, to explore the configuration conditions of export-oriented supply chains dominated by agri-SMEs and their impact on sustainable development in rural Japan. It examines five agricultural export supply chains in four regions from a meso-level perspective. The analysis offers a relatively uncommon comparative perspective on agricultural supply chains in Japanese rural areas, examining their economic, social, and environmental dimensions and thereby extending upon the predominantly economic focus of much existing supply chain research. In doing so, the study provides context-specific empirical insights that may help inform more integrated approaches to rural development policy.

This study addresses three research questions. First, in the production and processing stages of the supply chain, the agri-SMEs in the case studies upgrade their products and processing techniques in response to overseas market demand while organising contract farmers and building collaborative networks to ensure a high-quality, stable supply. Second, in the distribution and consumption stages, agri-SMEs coordinate with agricultural cooperatives, trading companies and direct export arrangements to develop export channels best suited to each product and market. In this process, they manage risks and comply with various certification and regulatory requirements while also leveraging regional brands, government support and territorial capital, together with their entrepreneurial agency, to construct and govern the supply chain. According to interviewees, the development of export-oriented supply chains appears to contribute to higher farm incomes and additional employment opportunities in rural areas. Beyond these economic outcomes, respondents also perceived socio-cultural and environmental benefits.

Second, the case analysis indicated that the achievement and distribution of these outcomes appeared to be associated with a combination of factors, including market demand, cooperative networks, business models, and regional capital. Because these factors vary across cases and interact in context-specific ways, they do not yet amount to a

single, unified analytical framework for the study as a whole. This underlines the importance of understanding the particularities of each SME-led supply chain, while also highlighting the need for further research on governance mechanisms and cooperation models that can operate across different contexts and support more diversified and sustainable development pathways in rural Japan.

Thirdly, these findings contribute to a key theme in sustainable rural development—the importance of context-specific, neo-endogenous development pathways—and reinforce the idea that there is no universal ‘silver bullet’ solution. The cases examined in this study suggest that promoting high-quality agricultural products through certification schemes and brand-building, fostering cooperative relationships and trust-based conflict-resolution mechanisms, and establishing direct connections with local consumers through field visits or resident staff are important elements in pursuing more diversified and sustainable rural development. Notably, in the cases analysed, market-oriented agri-SMEs appear able to combine local resources and expertise with international market demands by embedding themselves in regional cooperative networks, thereby contributing to the maintenance of regional distinctiveness while advancing selected sustainability goals in their specific contexts.

Data availability statement

The datasets presented in this article are not readily available because of confidentiality and ethical restrictions. Data will be made available on request. Requests to access the datasets should be directed to Tongxin Guo, 622d0s1@m.mie-u.ac.jp.

Ethics statement

Participant recruitment for this study began on February 5, 2024 and ended in December 1, 2024. All participants provided written informed consent. The retrospective component of this study was based on publicly available data obtained from the official websites of the respective research cases. Data access commenced on February 5, 2024. During the course of this study, the authors had access to certain information that could potentially identify individual participants. To ensure the protection of participant confidentiality and in accordance with ethical guidelines, all such data were anonymized prior to analysis and presentation in this article.

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Author contributions

TG: Formal analysis, Data curation, Methodology, Writing – original draft, Investigation, Software. YX: Validation, Writing – review & editing, Methodology, Software. ZC: Methodology, Validation, Investigation, Writing – review & editing, Formal analysis, Resources, Software. MA: Formal analysis, Writing – original draft, Data curation, Methodology, Visualization, Software, Conceptualization, Investigation, Resources.

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