An analysis of the sustainability and dynamics of short food supply chains

Pierre Chiaverina

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Présentée par Pierre Chiaverina
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Sous la direction de Sophie Drogué et Florence Jacquet

Devant le jury composé de

Pierre Dupraz, Directeur de recherche, INRAE	Rapporteur
Robert Finger, Professor, ETH Zurich	Rapporteur
Lisebeth Dries, Associate Professor, Wageningen University	Examinatrice
Goedele Van den Broeck, Assistant professor, University of Louvain	Examinatrice
Julie Subervie, Directrice de recherche, INRAE	Examinatrice
Sophie Drogué, Directrice de recherche, INRAE	Co-directrice de thèse
Florence Jacquet, Directrice de recherche, INRAE	Directrice de thèse

UNIVERSITÉ DE MONTPELLIER

L'INSTITUT agro Montpellier

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Abstract

Changing agriculture and food system is necessary to guarantee sufficient and nutritious food for all, while minimizing environmental impact and enabling producers to earn a decent income. Proponents of short food supply chains (SFSC) argue that they offer a promising pathway to sustainability. Despite this claim, there is a lack of robust quantitative evidence supporting the impact on sustainability of SFSC, and some research even raises skepticism about their actual benefits. In addition, most studies overlook the heterogeneous nature of SFSC when assessing their sustainability, which could be attributed to the tendency of researchers to view SFSC in binary opposition to conventional supply chains. SFSC is a wide term covering a variety of marketing forms such as direct sales in farmers' stores or at farmers' markets, box schemes, internet selling etc. Some qualitative studies also highlight that farmers' involvement in SFSC fluctuates over time and shows significant hybridization with conventional supply chains. However, these findings are based on studies that lack robust quantitative evidence. Thus, this thesis pursues a twofold objective. Firstly, it explores the dynamics of participation within these channels, and the factors that influence them. Secondly, it evaluates the causal effects of farmer engagement in SFSC on both economic and environmental sustainability.

The manuscript, organized into four chapters, begins with a literature review of the motivations and factors favoring and barriers constraining farmer participation in SFSC, as well as the impact on their income. The second chapter uses a mixed-Markov chain model to examine the dynamics of farmer engagement in direct-to-consumer (DTC) channels, and its determinants. It shows that DTC channel engagement in France has remained low and stable since 1970, while characterized by a significant hybridization with conventional supply chains. In addition, it demonstrates that farmers involved in DTC channels have a high probability over time to decrease their involvement in direct sales or even completely abandon them. Factors such as an increase in farmland size, a decrease in farm profitability, and the COVID-19 crisis contribute to increase this phenomenon. The third chapter, published in *Agricultural Economics*, extends the first two chapters

by investigating more in depth the effect of SFSC participation on farmers' income. The analysis underscores the ambiguity of the relationship between SFSC participation and farmer income, while depending on geographical location and the type of the economic performance indicator used. In the final chapter, published in *Ecological Economics*, the focus shifts to the effect of SFSC participation on farmers' synthetic pesticide use, using a multinomial endogenous treatment effect model. It demonstrates a significant reduction effect, albeit varying based on the specific SFSC type chosen by farmers.

This thesis makes a significant contribution to the ongoing discussion surrounding the sustainability of SFSC while offering crucial insights into their evolution and dynamics. It addresses gaps in prior research by providing quantitative evidences from large datasets and econometric methods controlling for potential omitted confounding variables. It shows that bypassing intermediaries can contribute to improving the sustainability of the current food system, while highlighting the dynamic and hybrid nature of SFSC.

Keywords: short food supply chains, sustainability, applied econometrics

Résumé

Il est nécessaire de repenser le système alimentaire afin de garantir une alimentation suffisante et nutritive pour tous, tout en minimisant son impact sur l'environnement et en permettant aux producteurs de gagner un revenu décent. Les défenseurs des circuits courts (CC) soutiennent qu'ils sont un levier intéressant pour promouvoir un système alimentaire plus durable. Cependant, malgré cette affirmation, des preuves quantitatives solides de l'impact des CC en matière de durabilité font défauts, et certaines recherches suscitent même un certain scepticisme quant à leurs bénéfices réels. De plus, la plupart des études ne prennent pas suffisamment en compte la nature hétérogène des CC lorsqu'elles évaluent leur durabilité. Cela s'explique en partie par une tendance dans le monde académique à percevoir les CC comme étant opposés aux circuits de commercialisation conventionnels. Les CC couvrent une grande variété de formes de commercialisation telles que les ventes directes dans les magasins de producteurs ou sur les marchés, la vente sur Internet, etc. Certaines études qualitatives soulignent que l'implication des agriculteurs dans les CC fluctue dans le temps et montrent une hybridation significative avec les circuits longs. Cependant, ces conclusions sont basées sur des études qui manquent de preuves quantitatives solides. Cette thèse poursuit donc un double objectif. Premièrement, elle explore la dynamique de la participation en CC des agriculteurs et les facteurs qui l'influence. Deuxièmement, elle évalue les effets causaux de l'engagement des agriculteurs dans les CC sur la durabilité économique et environnementale.

Le manuscrit, organisé en quatre chapitres, commence par une revue de la littérature des motivations et des facteurs favorisant et des obstacles limitant la participation des agriculteurs en CC, ainsi que de l'impact sur leurs revenus. Le deuxième chapitre utilise un modèle de chaîne de Markov mixte pour examiner la dynamique de l'engagement des agriculteurs dans les circuits de vente directe (CVD) et ses déterminants. Il montre que l'engagement dans les CVD en France est resté faible et stable depuis 1970, tout en se caractérisant par une hybridation importante avec les circuits de commercialisation longs. En outre, il démontre que les agriculteurs impliqués dans les

CVD ont une forte probabilité de diminuer leur implication en ventes directes avec le temps, voire de les abandonner complètement. Des facteurs tels que l'augmentation de la taille des surfaces agricoles, la diminution de la rentabilité des exploitations et la crise du COVID-19 contribuent à accroître cette probabilité. Le troisième chapitre, publié dans *Agricultural Economics*, prolonge les deux premiers chapitres en étudiant plus en profondeur l'effet de la participation en CC sur le revenu des agriculteurs. L'analyse souligne l'ambiguïté de la relation entre la participation en CC et le revenu des agriculteurs, qui dépend de la situation géographique et du type d'indicateur de performance économique utilisé. Le dernier chapitre, publié dans *Ecological Economics*, s'intéresse à l'effet de la participation en CC sur l'utilisation de pesticides de synthèse par les agriculteurs, à l'aide d'un multinomial endogenous treatment effect model. Il démontre un effet de réduction significatif, bien que variable en fonction du type de CC choisi par les agriculteurs.

Cette thèse apporte une contribution significative à la discussion en cours sur la durabilité des CC tout en offrant des perspectives cruciales sur leur évolution et leur dynamique. Elle comble les lacunes des recherches antérieures en fournissant des preuves quantitatives à partir de vastes ensembles de données et de méthodes économétriques contrôlant pour d'éventuels biais d'endogenéité. Elle montre que la suppression des intermédiaires peut contribuer à améliorer la durabilité du système alimentaire actuel, tout en soulignant la nature dynamique et hybride des CC.

Mots-clés: circuits courts, durabilité, économétrie appliquée

Contents

Introduction

In recent decades, academia and policy-makers have shown a growing interest in local food systems (LFS) and short food supply chains (SFSC), often designated as alternative food networks (AFN). Their development has been encouraged in the European Union (EU) by the European Agricultural Fund for Rural Development (EAFRD) devoting up to 10% of its expenditures to the promotion of food chain organization (Dwyer et al., 2016). Similarly, the U.S. Department of Agriculture invested $501.5 million over 5 years in diverse programs promoting local food production through the 2014 Farm Bill (Martinez, 2016). This growing interest in SFSC can be attributed to significant transformations within the food-retailing sector during the latter half of the 20th century as well as the potential sustainable benefits of SFSC (Renting, Marsden, & Banks, 2003; Van Der Ploeg et al., 2000).

With increasing concentration in the food-retailing sector and the development of vertical integration, retailers have increasingly sought to minimize their costs by committing to a limited number of farmers capable of meeting high volumes and quality standards (Richards, Bjørkhaug, Lawrence, & Hickman, 2013; Saitone & Sexton, 2017; Sexton, 2013). These significant changes in the food retailing sector have encouraged farmers to improve production efficiency and increase volume, while also increasing the difficulties of negotiating favorable prices and meeting retailers' requirements (Dries, Reardon, & Swinnen, 2004; Renting, Marsden, & Banks, 2003; Van Der Ploeg et al., 2000). Moreover, the growing concentration within food-retailing sector has coincided with the implementation of liberalized agricultural policies post-1990 in the EU, substituting price regulations with direct income support. This shift has led to amplified price volatility for farmers, linked more closely to global market prices (Swinnen, Olper, & Vandevelde, 2021). In response to growing income pressures, many farmers have adopted innovative strategies such as establishing direct links with consumers to augment the value of their products (Saitone & Sexton, 2017; Van Der Ploeg et al., 2000). Farmers can get a higher price in SFSC because the tangible and intangible

qualities of their products (e.g. authenticity, safety and trust) that allow them to command a price premium are more easily recognized when the link with the consumer is closer (Flaten, Lien, Koesling, & Løes, 2010; González-Azcárate, Cruz-Maceín, & Bardají, 2022).

On the demand side, increased public concerns about ecological, health, and animal welfare issues, along with growing distrust in conventionally produced food caused by numerous food scandals, have resulted in an increased consumer demand for higher product quality and differentiation (Renting et al., 2003; Saitone & Sexton, 2017; Sexton, 2013). Specifically, consumers have shown a notable interest in establishing direct links with farmers, based on transparency, trust and shared values, in order to reduce their concerns about conventionally produced food (Renting et al., 2003; Weatherell, Tregear, & Allinson, 2003; Winter, 2003). This shift in consumer expectations towards quality may have encouraged farmers to join SFSC.

In the European Union, SFSC refer to supply chains with "a reduced number of intermediaries", generally involving no more than one intermediary from the producer to the consumer (Kneafsey et al., 2013). In France, SFSC have been officially defined by the French Ministry of Agriculture as a marketing mode involving no more than one intermediary between the producer to the consumer (LOI N° 2010-788, 2010; LOI N° 2010-874, 2010). This encompasses both direct sales, through direct-to-consumer (DTC) channels such as farmers' markets, and sales via a single intermediary, known as direct-to-retailer (DTR) channels, which could include outlets like canteens or supermarkets. In contrast, there is no official definition of LFS, which have a strong subjective aspect related to local context. It refers most of the time to a distance of about 10–30 miles up to 100 miles between the point of production and the point of sale (Feldmann & Hamm, 2015) but can also be understood in relation to a recognized geographical area such as a county or a national park. These two concepts are often confused because SFSC embrace diverse retailing channels, overlapping most of the time the local concept. However, SFSC refers to the nature of the relationship between producer and consumer, whereas LFS designate the geographical distance between them (Kneafsey et al., 2013).

In this thesis, we refer to SFSC, as it is a more precise concept than LFS, and benefits from a legal definition. Another reason is that we are interested about the sustainable impacts of eliminating intermediaries rather than the impact of the distance traveled by farm products before reaching consumers. There is an increasing inclination to consider improving supply chains as a mean to attain and contribute to a more sustainable food system (Bush, Oosterveer, Bailey, & Mol, 2015). The sustainable benefits of SFSC have been widely praised, especially for farmers, consumers, and rural communities. SFSC have been argued to provide ecological benefits through decreased food miles and carbon emissions, while also favoring the adoption of sustainable farming practices. From a socio-economic perspective, it has been claimed that SFSC can contribute to improve farmers' income, economic development in rural areas, consumers' access to healthy food and social interactions around growing and eating of food (Enthoven & Van den Broeck, 2021; Kneafsey et al., 2013).

However, very little quantitative evidence on the impacts of SFSC exists and some research even raises skepticism about their actual benefits (Tregear, 2011). In particular, some findings cast doubt on the social integration of SFSC (Brown, Dury, & Holdsworth, 2009; Guthman, 2008; Hinrichs, 2000; Hinrichs & Allen, 2008), their alleged positive environmental influence (Coley, Howard, & Winter, 2011; Edwards-Jones et al., 2008) and economic impacts (Kneafsey et al., 2013). In addition, as the local trap critic points out, there is a tendency among scholars to conflate the structural characteristics of SFSC with desirable outcomes and the motivations of their protagonists (Born & Purcell, 2006; Tregear, 2011). One reason is that there is a widely accepted assumption in the scientific literature, which supposes that SFSC mainly attract farmers who give priority to non-economic objectives, or that they inherently deliver more sustainable outcomes. This therefore leads to romanticize the impact of SFSC on sustainability in the literature, and to question their real sustainable contribution.

The local trap emphasizes the need to assess the effects of SFSC based on an "agnostic frame of mind", without being influenced by any preconceived beliefs about their outcomes (Tregear, 2011). It supposes that there are no proven inherent beneficial outcomes to SFSC, but that

eliminating intermediaries could contribute to improve the sustainability of the current food system, by acting through various causal mechanisms. These mechanisms vary depending on the outcome considered. For instance, SFSC participation might increase farmers' income by allowing farmers to capture a greater portion of the consumers' expenditure on food and obtaining a price premium. SFSC might positively influence rural development by increasing income retention in the local economy and reduces synthetic pesticide use thanks to less standardized marketing requirements.

The local trap also shows the importance of addressing endogeneity concerns when estimating the causal impact of SFSC on food system sustainability, and specifically controlling for farmers' underlying motivations and intrinsic characteristics. It suggests that the effects of SFSC might not depend on eliminating intermediaries per se, but on the agenda and attributes of those that choose the shortening strategy. Consequently, eliminating intermediaries would not lead inherently to greater sustainability but to where participating farmers want it to lead (Born & Purcell, 2006; Tregear, 2011). SFSC participation may therefore be endogenous, due to unobserved or unidentified variables affecting farmer adoption of SFSC and correlated with sustainability outcomes. Without accounting for omitted variable bias, the resulting parameter estimates are likely to be biased and may therefore yield incorrect conclusions about the sustainable impacts of SFSC.

In addition, the highly heterogeneous nature of SFSC poses challenges in analyzing their sustainability. SFSC is a wide term covering a variety of marketing forms such as direct sales in farmers' stores or at farmers' markets, box schemes, Internet selling etc. Some qualitative studies have shed light on the existence of hybrid marketing strategy that combines both SFSC and conventional supply chains (Aubry & Kebir, 2013; Benedek, Fertő, & Molnár, 2018; Filippini, Marraccini, Houdart, Bonari, & Lardon, 2016; Sellitto, Vial, & Viegas, 2018; Zwart & Wertheim-Heck, 2021). Qualitative research also finds that farms engaged in SFSC frequently shift in and out of conventional supply chains due to economic reasons (B. Ilbery & Maye, 2006; Brian Ilbery & Maye, 2005a, 2005b; Brian Ilbery, Maye, Kneafsey, Jenkins, & Walkley, 2004). Although these findings suggest that SFSC participation fluctuates over time and is characterized by a significant degree of hybridization with the conventional supply chain, they are drawn from studies that lack

robust quantitative evidence. The majority of studies overlook the complex nature of SFSC and instead rely on a simplistic binary variable to designate farms engaged in SFSC when assessing their causal impact on sustainable factors. Neglecting the heterogeneity of SFSC can be problematic, as the sustainability impact of SFSC involvement can vary based on the degree and dynamics of participation and types of channels used (Enthoven & Van den Broeck, 2021). This binary approach reflects the traditional tendency to define SFSC in opposition to conventional supply chains, and more specifically as a form of protest against the conventional system. In contrast, the hybrid and dynamic nature of SFSC might suggest that farmers involved in SFSC do not inherently possess distinct motivations compared to those participating in conventional supply chains (Tregear, 2011).

Thus, this thesis pursues a twofold objective. First, this thesis investigates the historical evolution and the dynamics of farmer participation in SFSC based on large longitudinal datasets. It analyzes how economic factors – such as the profitability of farming activities, farm size, average income around farm city, and the COVID-19 crisis – affect the dynamics of farmer engagement in SFSC. The literature currently lacks crucial quantitative evidence concerning the evolution and dynamics of participation in SFSC. Such evidence is essential for gaining insightful understanding of SFSC and to improve the evaluation of their impact in future research. Second, it evaluates the causal effects of farmer participation in SFSC on both their economic performance and their use of synthetic pesticides. It addresses gaps in prior research by providing robust quantitative evidence on the economic and environmental sustainability of SFSC using large datasets and econometric methods controlling for potential omitted confounding variables. In addition, it contributes to the literature by taking into account the heterogeneity of SFSC when evaluating their sustainability, and notably by distinguishing between different types of SFSC.

In the first chapter of this thesis, “Farmers’ involvement in short food supply chains: a systematic literature review”, we conduct a systematic review of the motivations and factors favoring and barriers constraining farmers’ participation in SFSC, as well as the impact on their income. It includes 146 papers among 2226 scientific articles returned by the literature search from Web of Science and Scopus databases between 2000 and 2021 using the PRISMA method. We show

that both economic and non-economic motivations encourage farmers to produce for SFSC with mixed evidence on which is the primary motivation. Furthermore, we demonstrate that the reasons farmers engage in SFSC differ based on their geographic location, the specific type of SFSC, and certain characteristics specific to the farmers involved. A set of characteristics of the farmers, farms and the area where the farms are located drive SFSC involvement. Younger, female and more educated farmers are more inclined to market through SFSC. Small farmers who grow more diversified high value crops and animal products with more environmental friendly methods are more likely to participate in SFSC. Farms that participate in SFSC also rely more on family labor and non-agricultural activities. In addition, opportunities associated with SFSC increase with variables characterizing the farmer contextual environment including population density, income, and education level of the population. We also demonstrate that numerous constraints impede the development of SFSC, and we find a mixed effect of SFSC participation on farmers' income. Engaging in SFSC improves farmers' income by enabling them to capture a greater share of consumers' food expenditure, obtaining a premium for their produce and reducing the variability of the prices they receive (Mundler & Jean-Gagnon, 2020; Park, Mishra, & Wozniak, 2014; Park, Paudel, & Sene, 2018; Uematsu & Mishra, 2016). However, SFSC farmers have limited sale volume while facing higher production and commercialization costs, including significant expenses for labor, packaging, and transportation, as well as transaction costs such as those associated with acquiring information, negotiation, and control. They may even have to set prices that do not adequately cover their production costs due to intense competition with other SFSC and a deep social commitment to their community resulting in self-exploitation (Galt, 2013; Galt, Bradley, Christensen, Kim, & Lobo, 2016).

In the second chapter of this thesis, "The evolution and dynamics of farmers' engagement in direct-to-consumer channels", we analyze the evolution and dynamics of participation in DTC channels based on data from the French Agricultural Data Network and French Agricultural Census. As noted above, the literature lacks robust quantitative evidence on the dynamics of participation in DTC channels, as researchers tend only to view SFSC in binary opposition to conventional supply

chains. In addition, farmers involved in DTC channels face a number of problems that can lead them to decrease their direct sales or even abandon them (Argüelles, Anguelovski, & Sekulova, 2018; Stephenson, Lev, & Brewer, 2008). In particular, farmers could opt to decrease their reliance on DTC channels due to scaling up difficulties, lack of profitability and demand as well as short-term shocks such as the COVID-19 crisis. Hence, we employ a mixed-Markov chain model to examine how certain economic factors influence the dynamics of farmers' involvement in DTC channels and, more specifically, the likelihood of a decrease in their involvement.

In contrast to studies indicating a rise in participation in DTC channels, our study reveals a pattern of consistently low and stable engagement since 1970. Despite a recent surge between 2010 and 2020, participation in DTC channels experienced a decline during the COVID-19 crisis. This finding might suggest that DTC channels are far from surpassing their niche status and being able to meet large food demand. In addition, we find that the predominant approach to engaging with DTC channels involves adopting a hybrid strategy that combines both DTC channels and longer supply chains. A hybrid marketing approach can help farmers engaged in DTC channels to minimize their marketing risks by providing access to a larger and steadier customer base and facilitating the transfer of surplus products between different channels. We also show that farmers involved in DTC channels have a high probability over time to decrease their involvement in direct sales or even completely abandon them. Such evidence gives insights into the dynamic nature of DTC channels, indicating their capacity to make supply chain adjustments in response to economic imperatives or opportunities.

As the size of farmland expands, there is an increased probability that farmers engaged in DTC channels will decrease their direct sales. Additionally, this expansion reduces the likelihood of farmers exclusively involved in LFSC to engage in DTC channels, which might be due to the presence of various constraints that hinder the scalability in DTC channels. Similarly, the COVID-19 crisis raised the likelihood of shifting from participation in DTC channels to an exclusive involvement in LFSC, while decreasing the opposite probability. One explanation is the enforcement of social distancing measures, which resulted in the temporary closure of face-to-face

markets, like farmers' markets. As their net income decreases, farmers highly involved in DTC channels are more likely to reduce their direct sales for hybrid marketing approach, while those with a hybrid marketing approach are more likely to participate exclusively in LFSC channels. In addition, we find that farmers exclusively involved in LFSC, making a transition to DTC channels, are not undertaking this transition due to profitability challenges within LFSC. We find an ambivalent effect of an increase in average income near the farm city. Our findings demonstrate that it motivates farmers solely engaged in LFSC to transition to DTC channels, while simultaneously prompting farmers highly involved in DTC channels to abandon them for LFSC. For farmers who use a hybrid marketing strategy, it reduces the likelihood of transitioning exclusively to LFSC but also of relying on direct sales for more than 75% of total sales. Such ambivalent effect could stem from the fact that an increase in average income contributes to an increase demand for local food but also competition among farmers involved in DTC channels.

Overall, this chapter emphasizes the importance of moving beyond a simplistic view of farmers' involvement in DTC channels. Taking into account the hybrid and dynamic involvement of farmers in DTC channels is therefore crucial, especially when assessing their impact on sustainability and designing policies to support them.

The third chapter of this thesis, "Does short food supply chain participation improve farm economic performance? A meta-analysis" extends the first two chapters by investigating more in depth the effect of SFSC participation on farmers' income. Through a meta-analysis using a logistic regression model, we identify key factors to explain differences between studies that find better economic performance in SFSC and those that do not. Our meta-analysis consists of 48 studies published in English and French from 2000 to 2022 that examine the economic performance of farms engaged in SFSC. Based on far more empirical evidence than previous reviews, we find that the relationship between SFSC participation and farmer income remains ambiguous. More specifically, the findings indicate that the reported effect of SFSC on a farm economic performance varies depending on location and the indicator used to capture the economic performance of farms. Studies conducted in Europe are more likely to report higher farmer income than those in North

America, as are studies that use profit satisfaction metrics rather than measures of gross or net income.

This result does not indicate that all European farmers participating in SFSC are successful. Cesaro et al. (2020) show that SFSC adoption does not significantly affect farm performance in the majority of European member states. Differences in economic performance between Europe and US might be explained by the specific differences in agricultural and marketing systems between these areas. Specifically, lower economic performance found in the US may be partly explained by the greater prevalence of community-supported agriculture farmers than in Europe (7398 farms in the US against 2783 in Europe in 2015, despite there being more farms in Europe (URGENCI, 2016; Martinez & Park, 2021)) who prioritize non-economic motivations more than participants in other forms of SFSC (Schoolman, Morton, Arbuckle, & Han, 2021). Differences in economic performance between Europe and the US might also be attributed to differences in the policy support for producers in SFSC.

We also demonstrate that better economic performance of SFSC is more likely to be found in studies using profit satisfaction rather than gross or net income. This might be explained by the fact that subjective rating reflects a broader view of farm performance than objective measures focused on more specific financial indicators. Subjective rating can reflect performance at the household level including income sources beyond the production and marketing of agricultural goods such as from non-farm activities and off-farm work. It could suggest that farmers involved in SFSC might earn an adequate income by supplementing their income from agricultural activities with non-agricultural income. Another possible explanation is that selling locally and directly to consumers for many producers is a great source of enjoyment and there are benefits for the community that might compensate their relatively low monetary return (Sage, 2003; Silva, Dong, Mitchell, & Hendrickson, 2015).

In the fourth chapter, “Do farmers participating in short food supply chains use less pesticides? Evidence from France”, we investigate the effect of farmers’ involvement in different types of SFSC on synthetic pesticide use. In particular, we consider the impact on synthetic

pesticides occurring from participating in (i) DTC channels, (ii) DTR channels and (iii) a combination of both DTC and DTR channels, compared to participation only in long food supply chains (LFSC). In assessing the environmental sustainability of SFSC farmers, research has primarily focused on their greenhouse gas emissions. Conversely, there has been limited research attention given to the use of synthetic pesticides by SFSC farmers, despite their significant role in causing numerous adverse environmental and human health effects (Carvalho, 2017; Geiger et al., 2010). To answer this research question, we rely on data obtained from the 2020 French agricultural census and a national survey on the phytosanitary practices of market gardeners conducted in 2018. In addition, we employ a multinomial endogenous treatment effect model that accounts for endogeneity concerns.

We demonstrate that the effect of SFSC participation on farmers' synthetic pesticide use varies depending on the type of SFSC employed. Farmers who sell part of their vegetable crops through DTC channels use significantly fewer synthetic pesticides than those who only sell their crops through LFSC. All other things being equal, switching from marketing vegetables only in LFSC to also marketing in DTC channels leads to a 72% reduction of synthetic pesticide use. It suggests that DTC channels can be a lever to overcome socio-economic constraints that inhibit the reduction of pesticide use and the development of alternative farming practices. However, there is no evidence that farmers involved in DTR channels use significantly fewer synthetic pesticides. The only exception is when farmers combine both DTR and DTC sales, but the reduction effect is lesser than when the SFSC strategy includes only DTC sales.

Farming practices are strongly framed by the specifications of the marketing channels, which set prices and determine product types, assortments, and volumes as well as marketing standards. As in LFSC, farmers who sell part of their vegetables through DTR channels face marketing specifications that lock them into intensive farming systems (Mount & Smither, 2014; Zwart & Wertheim-Heck, 2021). They have to efficiently provide a large and regular supply of uniform products while complying with stringent marketing standards. For example, farmers are constrained by retailer requirements and consumer preferences to produce fruits and vegetables with a high

cosmetic standard (e.g., minimal pest damage and optimal size and color development), which often requires the use of synthetic pesticides (Pimentel, Kirby, & Shroff, 1993; Yue, Alfnes, & Jensen, 2009; Zakowski & Mace, 2022). In contrast, marketing requirements in DTC channels are less standardized, giving farmers room to implement more environmentally friendly farming practices (Lefèvre et al, 2020; Milford, Lien, & Reed, 2021). In addition, direct interactions between farmers' and consumers can even be considered as a substitute for organic certification, offering farmers a price premium without the financial, administrative and time requirements of organic certification. This price premium is crucial as it enables farmers to keep up with the disadvantages of potential yield losses associated with the adoption of reduced synthetic pesticide farming practices (Flaten et al., 2010; González-Azcárate et al., 2022). The more environmentally friendly farming practices associated with DTC channels may also be explained by their social dimension; offering farmers the opportunity to connect with each other. By favoring the exchange of knowledge and the sharing of alternative values, DTC channels promote the implementation of new practices and solutions and keep farmers' motivation high (Chiffoleau, Millet-Amrani, & Canard, 2016; Lamine, Meynard, Perrot, & Bellon, 2009; Zoll, Specht, & Siebert, 2021).

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Chapter 1

Farmers' involvement in short food supply chains: a systematic literature review

This work is joint with Sophie Drogué, Florence Jacquet, Larry Lev and Robert P. King

Abstract

Many researchers, policy makers and food activists view Short Food Supply Chains (SFSC) as levers for improving farm income and the sustainability of farming systems. We conduct a systematic review of the motivations and factors favoring and barriers constraining farmer participation in SFSC as well as the impact on their income. We examined articles published in English and French from January 2000 to September 2021 using the PRISMA method. The analysis includes a total of 146 papers among 2226 scientific articles returned by the literature search from Web of Science (WoS) and Scopus databases. The largest number of publications on these topics have been conducted on the United States (US) and have dramatically increased since 2014. The findings indicate that both economic and non-economic motivations encourage farmers to produce for SFSC with mixed evidence on which is the primary motivation. A set of characteristics of the farmers, farms and the area where the farms are located drive SFSC involvement. However, many constraints hinder the development of SFSC. In addition, even though the majority of studies report that SFSC participation has a positive impact on farmer income, some studies find the opposite result. Based on our results, research gaps are identified and policy suggestions drawn.

Résumé

De nombreux chercheurs, décideurs politiques et militants considèrent les circuits courts (CC) comme un levier pour améliorer le revenu des agriculteurs et la durabilité du système alimentaire. Nous effectuons une revue systématique des motivations et des facteurs favorisant et des barrières limitant la participation des agriculteurs aux CC, ainsi que de l'impact sur leur revenu. Nous avons examiné les articles publiés sur ces sujets, en anglais et en français, entre janvier 2000 et septembre 2021 à partir de la méthode PRISMA. L'analyse porte sur un total de 146 articles parmi les 2226 articles scientifiques issus de la recherche documentaire dans les bases de données Web of Science et Scopus. Les résultats indiquent que des motivations à la fois économiques et non économiques encouragent les agriculteurs à participer en CC, avec des preuves mitigées quant à leurs motivations principales. Un ensemble de caractéristiques des agriculteurs, des exploitations agricoles et de la région où elles sont situées affectent la décision de participer en CC. En outre, même si la majorité des études indiquent que la participation en CC a un impact positif sur le revenu des agriculteurs, certaines études montrent le contraire.

1.1 Introduction

Local food systems (LFS) and short food supply chains (SFSC) have garnered increasing interest from academia and policy-makers in recent decades. The growing concern of consumers with food provenance and quality and the increasing pressure on the value captured by farmers in conventional supply chains have contributed to their emergence (Marsden, Banks, & Bristow, 2000; Renting, Marsden, & Banks, 2003). Their development has been encouraged in the European Union (EU) by the European Agricultural Fund for Rural Development (EAFRD) devoting up to 10% of its expenditures to the promotion of food chain organization (Dwyer et al., 2016). Similarly, the U.S. Department of Agriculture invested over $1 billion to support local food projects between 2009 and 2014 (Vilsack, 2016). A growing number of farmers have chosen to market through SFSC and LFS even though this growth appears to be plateauing in the US (Low et al., 2015). By 2015, 15% of EU farms sold more than half of their production directly to consumers (European Parliamentary Research Service, 2013). In 2012, 7.8% of U.S. farms marketed food locally with 70% of them using only direct marketing channels (Low et al., 2015).

There is no official distance below which the term "local" can be used. Most of the time authors refer to a distance of around 10 to 30 miles up to a radius of 100 miles between the point of production and the point of sale (Feldmann & Hamm, 2015). By contrast, the EU has adopted since 2013 a common definition of SFSC, defined as a supply chain including a minimal number of intermediaries (Regulation (EU) No 1305/2013). The dividing line between LFS and SFSC is blurred because SFSC embrace diverse forms overlapping most of the time the local concept, regrouped in the “sales in proximity” category (Aubry & Chiffoleau, 2009). The European literature therefore refers mainly to SFSC owing to the difficulties of defining the “local” concept. In addition, most studies included in this review do not look at SFSC but something more restrictive such as direct marketing (DM) or some component of DM such as community-supported agriculture (CSA) or farmer markets (FM).

The identification of the determinants and motivations driving farmer participation in SFSC is important because of the matured local food environment and the policy interest in using these channels as levers for improving food sustainability. Proponents of these alternative food networks (AFN) argue that they improve farm income through the reduced number of intermediaries, reconnect farmers with consumers and offer better access to fresh and seasonal produce. These AFN also have been associated with more environmentally friendly farming practices and a lower carbon footprint from a reduction of food miles. However, SFSC suffer from numerous obstacles hindering their adoption and performance (Plakias, Demko, & Katchova, 2020; Rucabado-Palomar & Cuéllar-Padilla, 2020). Despite offering a price premium, their positive impact on farm viability has been questioned because of high costs and labor requirements (Uematsu & Mishra, 2016). In addition, some studies have called into question their social embeddedness as being the preserve of white, educated and wealthy customers (E. Brown, Dury, & Holdsworth, 2009; Guthman, 2008; Hinrichs, 2000; Hinrichs & Allen, 2008) and their capacity to reduce food carbon footprint due to low sale volumes (Coley, Howard, & Winter, 2011; Edwards-Jones et al., 2008).

To the best of our knowledge, there are two reports and one article that provide a comprehensive overview of SFSC and LFS (Enthoven & Van den Broeck, 2021; Kneafsey et al., 2013; Martinez et al., 2010). Although their work represents a solid contribution to enhanced understanding of SFSC and LFS, they address insufficiently the issue of farmers' involvement and do not follow a systematic review protocol (Martinez et al., 2010). In addition, they are mainly focused on defining these systems and providing a broad view of their impacts (Enthoven & Van den Broeck, 2021; Kneafsey et al., 2013). To address these gaps, we conduct a systematic review of the motivations and factors favoring and barriers constraining farmer participation in SFSC as well as the impact on their income. Our systematic review on SFSC is the first exclusively concentrated on farmers, which allows a more detailed analysis. This literature review focuses on farmers for three reasons. First, SFSC can provide farmers, in particular smallholders, significant opportunities. Second, the public sector can influence SFSC development through policies

(Kneafsey et al., 2013). Finally, a review from the consumer perspective has already been conducted, identifying main factors influencing local food purchases (Feldmann & Hamm, 2015).

The paper is structured as follows. The next section provides a description of the systematic review protocol used, followed by an overview of the studies included in the review. The results section is divided in four parts. The first part examines what motivates farmers to produce for SFSC. The second part analyses the characteristics of the farmers, farms and of the area where the farms are located in determining the farmers‘ marketing choice. The third part addresses the barriers hindering the implementation of SFSC. The fourth part investigates the impact of SFSC on farmers' income. In the last section, we draw conclusions from our findings and present recommendations for future research and policy implications.

1.2 Method

This literature review identifies all the articles investigating the characteristics, motivations and constraints for farmers involved in SFSC, as well as the impact on their income. It is performed by following the checklist of the Preferred Reporting Items for Systematic Reviews and Meta-analyses (PRISMA) (Liberati et al., 2009) (Figure A1.1). The PRISMA method increases the reliability and transparency of literature reviews by preventing arbitrary decision making during the review procedure and can be easily replicated. Extensively used in health sciences, it is becoming a recognized standard in many other domains of the scientific research as social sciences. The review protocol containing information of the search terms, databases, eligibility criteria and selection process is presented below.

1.2.1 Information sources and literature search

The literature review was conducted using Scopus and Web of Science databases that are among the most highly valued databases for this field of interest. We applied a combination of three lists of search terms detailed in Table A1.1, which explored the article title, abstract and keywords of every published document identified. The list including “Farmer” or “Producer” keywords was

mainly used in order to avoid an overflow of unsuitable articles. Additional filters were used in order to limit the search within the social science discipline. The last search was run on September 27th 2021.

1.2.2 Eligibility criteria

The Population, Intervention, Comparison, Outcomes, and Study (PICOS) design criteria was used to identify both qualitative and quantitative papers (Table A1.2). All English or French articles published in peer-reviewed journals from January 2000 to September 2021, analysing characteristics, motivations, and constraints for farmers engaged in SFSC participation, as well as the income impact are included. We therefore excluded from this literature review, articles not responding clearly to the four above-mentioned objects of research and supply chain characteristics. Studies not conducted in Europe, Northern America or Australia where the specific context could induce different outcomes were also excluded. Finally, literature reviews, theses and dissertations, letters, book chapters, reports, authors' comments, and other grey literature were not taken into account.

1.2.3 Study selection process

The selection of articles among the 2226 records after removing duplicates between Scopus and Web of Science databases was conducted in three rounds (Figure A1.1). First, two independent reviewers screened article titles and abstracts on an Excel spreadsheet while disagreements between them were resolved through discussion. During this phase, 1939 records not meeting the eligibility criteria were excluded. Then, eligibility assessment was carried out by the lead author reviewing in detail the full-text of the 287 remaining articles. Among them, 150 records outside the scope of the review, not farmer specific or not conducted in Europe, Northern America or Australia were

removed. We finally added 9 original studies[1] to the 137 articles identified previously, leading to a total of 146 articles included in the literature review (Figure A1.1).

1.2.4 Data Collection Process

Content analysis was conducted by extracting for each of the selected articles the following information: authors, year, setting, supply chain characteristics, methodology, sampling, and the key findings with regard to the four aspects of SFSC examined (Table A1.3, Table A1.4, Table A1.5 and Table A1.6).

1.3 Results

1.3.1 Overview of the selected studies

The number of SFSC publications from the producers' perspective has dramatically increased since 2014, reflecting the increasing research interest in this topic. More than 71% of the publications were completed between 2014 and 2021 (Figure 1.1). They have mostly been conducted in the US (49%) and Italy (9%) and France (8%) (Figure 1.2). The larger number of US articles may be explained by the availability of data and because SFSC are further developed in this area.

Most of these publications rely on quantitative methods (59%, n =86), especially those investigating SFSC characteristics and their economic performance (Figure 1.1). Qualitative studies (26%, n = 38) are mostly used to examine motivations and barriers in addition to characteristics for studies relying on mixed method[2] (15%, n =22) (Table 1.1). Qualitative studies are mainly based on in-depth interviews and focus group discussions, better suited to evaluate farmers' motivations and

[1] These studies were retrieved when reading other ones identified by the PRISMA method and provide an important insight into the topics covered by our literature review. They were not identified through the review procedure mainly for two reasons. They are published in a journal not cover by the Scopus and Web of Science databases or missed a term in one of the three lists of comprehensive search terms detailed in their the article title, abstract or keywords.

[2] Articles based on mixed methods include studies combining quantitative (descriptive statistics, regression analysis methods, …) and qualitative analysis (interviews and focused group discussions).

barriers. Quantitative methods include mainly statistical analysis (descriptive statistics, factor analysis, non-parametric test) and statistical modelling (including OLS, probit, quantiles, and logit models) (Table 1.2). Regression analysis methods accounting for selection bias (e.g. Heckman model, treatment effect and selectivity approach for the multinomial logit model …) are used to estimate SFSC impact on farmers' performance. Selection bias occurs when unobservable factors (e.g. farmers' motivations) are correlated with SFSC participation and income. Quantitative methods also include modelling, spatial analysis, accounting analysis (Table 1.2).

The number of respondents from quantitative studies varies greatly, ranging from 3 to 1,653,000. By contrast, both mixed and qualitative studies display much lower variability, with their number of respondents not exceeding 169 and 48 respectively. This is due to the fact that they are mainly based on in-depth interviews. Twelve percent of the studies rely on samples that reflect the entire farm population (e.g. studies with samples based on census or representative sample data, Table 1. 3). Table A1.4**,** Table A1.5 and Table A1.6 provide details about what the comparison is to (general farming population when it is nationally representative or selection criteria for the survey). Representative studies are indicated in bold in the appendix so that they are distinguished from the studies based on non-representative samples[3].

[3] This convention is used so that the reader can recognize this key study characteristic without having to consult the Appendix tables

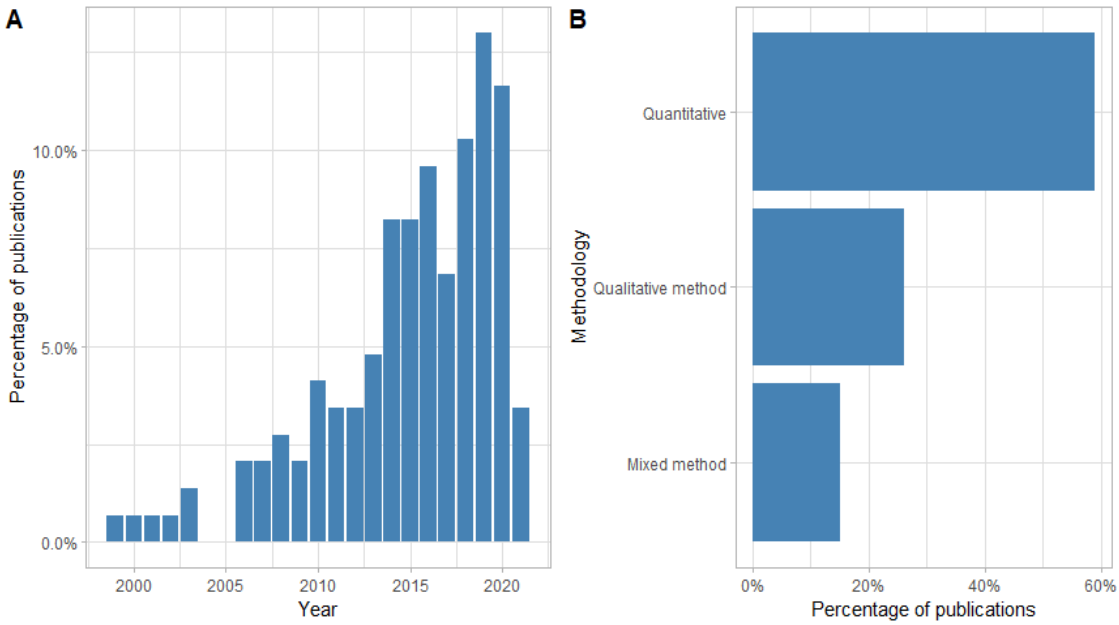

Figure 1.1. Percentages of publications by years and methodology

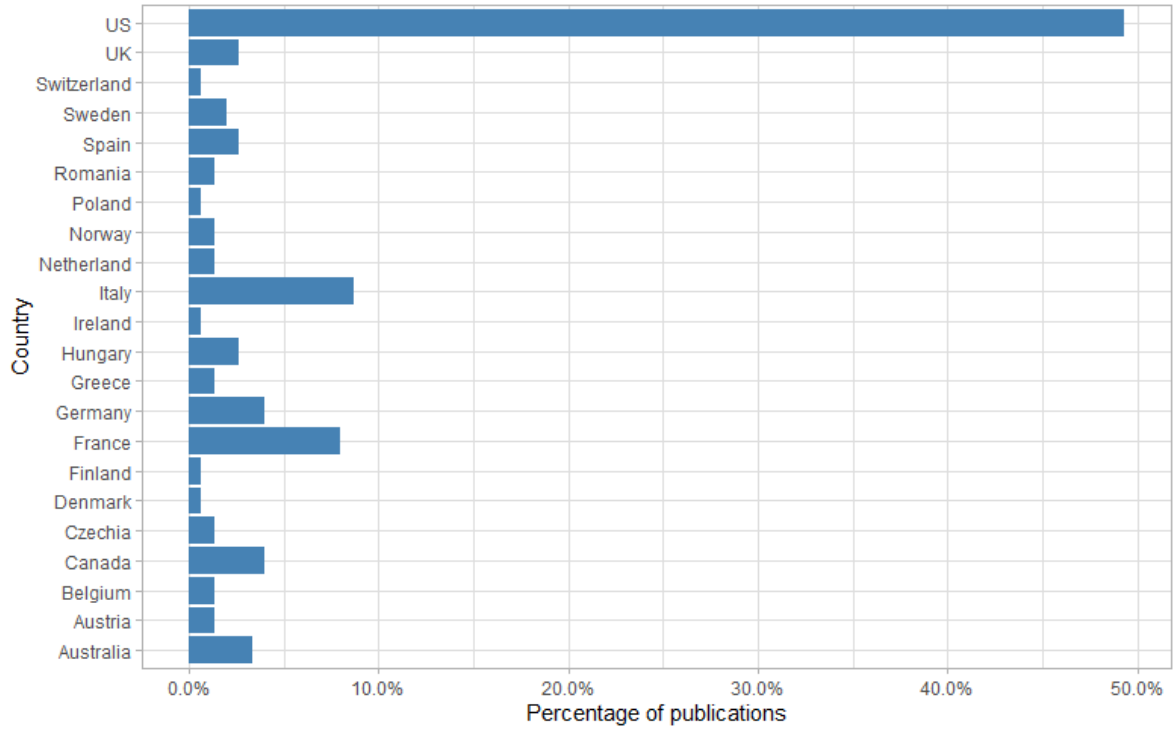

Figure 1.2. Percentages of publications by country

Table 1.1. Methods used to investigate characteristics, motivations, constraints and performance of farmers involved in SFSC

	Quantitative	Mixed Method	Qualitative
Motivations	18.6%	40.9%	57.9%
Characteristics	45.3%	27.3%	2.6%
Barriers	11.6%	36.4%	57.9%
Economic performance	43%	13.6%	7.9%
	N= 86[4]	N= 22	N= 38

Table 1.2. Quantitative method used

Statistical analysis	48.1%
Descriptive statistics (e.g. means, frequencies, correlation and percentages)	24.5%
Principal Component Analysis	11.8%
Non parametric tests	4.9%
Cluster analysis	6.9%
Spatial analysis	4.9%
Accounting analysis	3.9%
Modelling (e.g. simulation model, mixed-integer programming model, stochastic modeling)	3.9%
Statistical modelling	39.3%
Regression (e.g. OLS, logit, probit quantiles) and analysis of variance	32.4%
Regression analysis capturing selection effect (e.g. Heckman selection model, Multinomial endogenous treatment and stochastic Frontier Analysis)	6.9%
	N=86

Table 1.3. Percentage of studies representative of the general farming population

	Representativeness
Motivations	0% (n= 0)
Characteristics	28% (n= 17)
Barriers	2.4% (n=1)
Economic performance	12.3% (n= 7)
Total	12% (n=28)

1.3.2 Farmers' motivations

A large number of studies explore consumers' motivations for purchasing local food, valuing better quality, greater trust, local economy support, environmental benefits and animal welfare

[4] The N for each column in this table and the next one is the number of studies of each type. The percentages for the columns reach more than 100% to reflect that a single study can investigate different topics (e.g. motivations and characteristics) or relies on different quantitative methods (e.g. descriptive statistics and regression analysis).

(Feldmann & Hamm, 2015). Regarding the supply side, farmers' motivations often stem from dissatisfaction with conventional channels where farmers struggle to compete due to severe cost-price squeeze and entry barriers and feel they are losing control and autonomy over their business (Albrecht & Smithers, 2018; Beingessner & Fletcher, 2020; Drottberger, Melin, & Lundgren, 2021; Kessari, Joly, Jaouen, & Jaeck, 2020; Newsome, 2020; Tonner & Wilson, 2015).

Table 1.4 presents a comprehensive list of studies investigating farmer motivations for participating in SFSC depending on whether they are economic, non-economic, or both. Most of the studies agree that both economic and non-economic motivations encourage farmers to produce for SFSC (Table 1.4, column 1). Producers involved in SFSC are motivated by maximizing their profits or ensuring the economic viability of their farms. They can benefit from higher prices and margins, networking opportunities, payments in advance, low entry barriers and a reduction of economic risk and intermediary costs (Table 1.4, column 2). Farmers are also driven by social benefits (Table 1.4, column 3). They seek to offer consumers healthier and higher quality products at fair and steady prices and to educate consumers about food and farming. They value interactions and relationships with consumers based on trust and transparency and support the local community.

Non-economic motivations also include the political motivation of supporting alternative agriculture methods and AFN (Alkon, 2008; Beingessner & Fletcher, 2020; Drottberger et al., 2021; Jarosz, 2011; Kessari et al., 2020; Leiper & Clarke-Sather, 2017; Schoolman, Morton, Arbuckle, & Han, 2021), personal and philosophical motivations associated with changing individual life-work balance and doing something more meaningful (A. B. Bruce, 2019; Cleveland, Müller, Tranovich, Mazaroli, & Hinson, 2014; Drottberger et al., 2021; Fleury, Lev, Brives, Chazoule, & Désolé, 2016; Griffin & Frongillo, 2003; Jarosz, 2011; Leiper & Clarke-Sather, 2017; Ngo & Brklacich, 2014; O'Kane & Wijaya, 2015; Ross, 2006), motivations linked to the enjoyment of growing food, meeting and knowing customers (Drottberger et al., 2021; Fielke & Bardsley, 2013; Jarosz, 2011; Montri, Chung, & Behe, 2020), and environmental motivations resulting from ecological concerns encouraging farmers to work in harmony with nature (e.g. reducing pesticides) (Albrecht & Smithers, 2018; Alkon & Vang, 2016; A. B. Bruce, 2019; Cleveland et al., 2014; Drottberger et al.,

2021; Fielke & Bardsley, 2013; Fleury et al., 2016; Galt, 2013; Hvitsand, 2016; Jarosz, 2011; Lurie & Brekken, 2019; Migliore, Caracciolo, Lombardi, Schifani, & Cembalo, 2014; Migliore, Schifani, Romeo, Hashem, & Cembalo, 2015; Newsome, 2020; O'Kane & Wijaya, 2015; Ross, 2006; Sage & Goldberger, 2012; Salvatore Tudisca, Di Trapani, Sgroi, Testa, & Giamporcaro, 2014). In contrast to the literature, Schoolman et al. (2021) do not find strong environmental motivations for farmers involved in SFSC.

There is no consensus on the dominant motivations. On the one hand, some studies argue that farmers have opportunistic motivations with price and profit dominating in decision making (Alkon, 2008; Alkon & Vang, 2016; Demartini, Gaviglio, & Pirani, 2017; Germeten & Hartmann, 2017; Lea, Phillips, Ward, & Worsley, 2006; Oñederra-Aramendi, Begiristain-Zubillaga, & Malagón-Zaldua, 2018; Ross, 2006; Sitaker et al., 2020; Szabó & Juhász, 2015; Salvatore Tudisca et al., 2014; Visser, Trienekens, & Beek, 2013; Wubben, Fondse, & Pascucci, 2013). These farmers report benefiting from a monetary value thanks to their relationship with consumers considering embedded social values as part of their utility when they buy local goods (Demartini et al., 2017; Ross, 2006). In contrast, other studies report that farmers are not seeking profit maximization but value mainly connection with consumers for reasons other than economic benefits (Beingessner & Fletcher, 2020; Cleveland et al., 2014; D. Conner et al., 2012; Drottberger et al., 2021; Fielke & Bardsley, 2013; Galt, 2013; Goszczyński & Wróblewski, 2020; Hvitsand, 2016; Jarosz, 2011; Matts, Conner, Fisher, Tyler, & Hamm, 2016; Sage & Goldberger, 2012).

Table 1.4. Farmers' motivations for participating in SFSC

Economic and non-economic motivations	Economic motivations	Non-economic motivations
(Albrecht and Smithers, 2018; Alkon, 2008; Alkon and Vang, 2016; Andreatta and Wickliffe, 2002; Beingessner and Fletcher, 2020; Bruce, 2019; Cleveland et al., 2014; Conner et al., 2012, 2014; Demartini et al., 2017; Drottberger et al., 2021; Fielke and Bardsley, 2013; Fleury et al., 2016; Galt, 2013; Germeten and Hartmann, 2017; Griffin and Frongillo, 2003; Izumi et al., 2010; Jarosz, 2011; Kessari et al., 2020; Lea et al., 2006; Leiper and Clarke-Sather, 2017; Lurie and Brekken, 2019; Matts et al., 2016; Migliore et al., 2015, 2014; Montri et al., 2020; Newsome, 2020; O'Kane and Wijaya, 2015; Oñederra-Aramendi et al., 2018; Ross, 2006; Samoggia et al., 2019; Tudisca et al., 2014; Wubben et al., 2013)	(Aggestam et al., 2017; Albrecht and Smithers, 2018; Alkon, 2008; Andreatta and Wickliffe, 2002; Beingessner and Fletcher, 2020; Bruce, 2019; Cleveland et al., 2014; Conner et al., 2012, 2014; Cox et al., 2008a; Demartini et al., 2017; Fielke and Bardsley, 2013; Fleury et al., 2016; Germeten and Hartmann, 2017; Griffin and Frongillo, 2003; Izumi et al., 2010; Kessari et al., 2020; Lea et al., 2006; Leiper and Clarke-Sather, 2017; Migliore et al., 2014, 2015; Montri et al., 2020; Newsome, 2020; Oñederra-Aramendi et al., 2018; Ross, 2006; Samoggia et al., 2019; Sitaker et al., 2020; Szabó and Juhász, 2015; Tonner and Wilson, 2015; Tudisca et al., 2014; Visser et al., 2013; Wubben et al., 2013)	(Albrecht and Smithers, 2018; Alkon and Vang, 2016; Andreatta and Wickliffe, 2002; Åsebø et al., 2007; Beingessner and Fletcher, 2020; Bruce, 2019; Charatsari et al., 2018; Cleveland et al., 2014; Conner et al., 2012, 2014; Drottberger et al., 2021; Fielke and Bardsley, 2013; Fleury et al., 2016; Galt, 2013; Germeten and Hartmann, 2017; Goszczyński and Wróblewski, 2020; Griffin and Frongillo, 2003; Hvitsand, 2016; Izumi et al., 2010; Jarosz, 2011; Kessari et al., 2020; Leiper and Clarke-Sather, 2017; Lurie and Brekken, 2019; Matts et al., 2016; Migliore et al., 2015, 2014; Montri et al., 2020; Newsome, 2020; O'Kane and Wijaya, 2015; Oñederra-Aramendi et al., 2018; Sage and Goldberger, 2012; Samoggia et al., 2019; Tudisca et al., 2014; Wubben et al., 2013)

1.3.3 Determinants of SFSC participation

1.3.3.1 Farmers' characteristics

Farmers engaged in SFSC are relatively more likely to be neo-rural (Darolt et al, 2016; Farmer & Betz, 2016; Mundler & Jean-Gagnon, 2020) and female producers (Ahearn, Liang, & Goetz, 2018; Chen, Saghaian, & Tyler, 2019; Dong, Campbell, & Rabinowitz, 2019; Galt, Christensen, Beckett, & Myles, 2012; Mazzocchi, Corsi, & Ruggeri, 2020; Park, Paudel, & Sene, 2018; Silva, Dong, Mitchell, & Hendrickson, 2015). Only one study reports that male farmers are more likely to be engaged in SFSC (Rocchi, Randelli, Corsini, & Giampaolo, 2019). Corsi et al. (2018) show that the gender effect depends on the type of farming with higher SFSC engagement of female operators in horticulture but not in wine.

SFSC participation increases with the farmers' education level as it requires specific skills and abilities not always directly related to agricultural operations that more educated individuals may be more likely to develop (Andrei, ION, Luminita, Pop, & Marin, 2019; Benedek, Ferto, & Molnár, 2018; Bermond, Guillemin, & Maréchal, 2019; A. Bruce & Som Castellano, 2016; Chen et al., 2019; Farmer & Betz, 2016; Galt et al., 2012; Gilg & Battershill, 2000; Hunt, 2007; Silva et al., 2015; Uematsu & Mishra, 2016). For example, farmers in SFSC display greater management and marketing competencies (Charatsari, Kitsios, & Lioutas, 2020; Park, Mishra, & Wozniak, 2014; Plakias et al., 2020) and report higher internet use for advertising their products and obtaining key information (Ahearn et al., 2018; Detre, Mark, Mishra, & Adhikari, 2011; Park & Lohr, 2010; Park et al., 2014, 2018; Rocchi et al., 2019; Uematsu & Mishra, 2016). A few studies show a negative effect (Pölling & Mergenthaler, 2017) or non-significant effect of education on SFSC participation except when farmers pursue studies in agriculture (Rocchi et al., 2019).

Younger farmers are relatively more inclined to engage in SFSC because of their higher education level and interest in novelty (Benedek et al., 2018; Bermond et al., 2019; A. Bruce & Som Castellano, 2016; Chen et al., 2019; Detre et al., 2011; Dong et al., 2019; Galt et al., 2012; Hunt, 2007; Mundler & Jean-Gagnon, 2020; Mundler & Laughrea, 2016). On the other hand, a few studies report a higher participation of older farmers (Kacz, Hegyi, & Gombkötő, 2019) or a non-significant age effect (Ahearn et al., 2018; Rocchi et al., 2019; Silva et al., 2015).

Both farming experience and off-farm labor decisions have an inconclusive effect on SFSC participation. Some studies report that farmers with agriculture as primary occupation are more likely to use SFSC (Dong et al., 2019; Hunt, 2007; Uematsu & Mishra, 2016) while others find the contrary (A. Bruce & Som Castellano, 2016). Likewise, some studies support the conclusion that farming experience increases the odds that a farmer will use SFSC (Benedek et al., 2018; Galt et al., 2012; Plakias et al., 2020; Uematsu & Mishra, 2016) but others reach the opposite conclusion (Kacz et al., 2019; Park & Lohr, 2010) or an insignificant effect (Silva et al., 2015).

1.3.3.2 Farm characteristics

Most studies find that farms marketing through SFSC are of smaller size (Ahearn et al., 2018; Andrei et al., 2019; Auld, Thilmany, & Jones, 2009; Bermond et al., 2019; A. Bruce & Som Castellano, 2016; S. Corsi & Mazzocchi, 2019; Darolt et al., 2016; Detre et al., 2011; Dong et al., 2019; Farmer & Betz, 2016; Rosalia Filippini, Lardon, Bonari, & Marraccini, 2018; Galt et al., 2012; Hruška, Konečný, Smutná, & Duží, 2020; Mazzocchi et al., 2020; Mireille, 2009; Park & Lohr, 2010; Park et al., 2014; Plakias et al., 2020; Rocchi et al., 2019; Silva et al., 2015; Timmons & Wang, 2010; Salvatore Tudisca et al., 2014; Uematsu & Mishra, 2016). Fewer studies report that farms engaged in SFSC are of greater size (Benedek et al., 2018; Mundler & Jean-Gagnon, 2020; Mundler & Laughrea, 2016; Pölling & Mergenthaler, 2017). These four studies are based on surveys where small farms can be underrepresented (as compared to a Census). For example, Mundler and Jean-Gagnon (2020) targeted farmers advertising their participation in SFSC, which are mainly large farms with the ability to use advertisement. Rocchi et al. (2019) argue that the size effect depends on the farming sector with small farms more likely to engage in SFSC except in permanent crop sectors (e.g. wine, olive. They are also more likely to own their land (Farmer & Betz, 2016; Kacz et al., 2019).

High value crops (vegetables, fruits and tree nuts) and animal products are the most frequently represented types of production in SFSC (Bermond et al., 2019; Chen et al., 2019; Detre et al., 2011; Dong et al., 2019; Farmer & Betz, 2016; Hruška et al., 2020; Ilbery, Watts, Simpson, Gilg, & Little, 2006; Kacz et al., 2019; Mazzocchi et al., 2020; Plakias et al., 2020; Pölling & Mergenthaler, 2017; Rocchi et al., 2019; Timmons & Wang, 2010; Uematsu & Mishra, 2016). Horticultural products can be sold as harvested and even though meat, dairy and fruit products require some processing, they are predominantly made up of the primary product from which they originate. Farmers involved in SFSC are more likely to use organic or other environmentally friendly methods (e.g. less pesticides and fertilizers) (Ahearn et al., 2018; Aubert & Enjolras, 2016; Bermond et al., 2019; A. Corsi et al., 2018; S. Corsi & Mazzocchi, 2019; Detre et al., 2011; Rosalia Filippini, Marraccini, Lardon, & Bonari, 2016; Galt et al., 2012; Gilg & Battershill, 2000;

Mazzocchi et al., 2020; Mireille, 2009; Mundler & Jean-Gagnon, 2020; Mundler & Laughrea, 2016; Pépin, Morel, & van der Werf, 2021; Pölling & Mergenthaler, 2017; Rocchi et al., 2019; Schoolman, 2019; Tessier, Bijttebier, Marchand, & Baret, 2021) and more diversified production systems (Ahearn et al., 2018; Benedek et al., 2018; Björklund, Westberg, Geber, Milestad, & Ahnström, 2009; Darolt et al., 2016; Galt et al., 2012; Mireille, 2009). There are fewer studies showing that SFSC rely less on organic (Chen et al., 2019; Rosalia Filippini et al., 2018; Hruška et al., 2020; Kacz et al., 2019), less intensive (Rosalia Filippini et al., 2016) or diversified farming systems (Rosalia Filippini et al., 2018). They argue that organic certification is rather used to reach mainstream supply chains (Rosalia Filippini et al., 2018) while local demand for organic food is saturated in the US (Chen et al., 2019; Schoolman, 2019). Contrary to organic certification, there is no consensus on the effect of origin labels on SFSC participation. Some studies find that origin labels can be better exploited in conventional channels (Corsi et al., 2018) while the opposite effect is also reported (Corsi and Mazzocchi, 2019; Filippini et al., 2018).

The probability of using SFSC decreases with the use of production contracts (Ahearn et al., 2018; Benedek et al., 2018; Chen et al., 2019; Detre et al., 2011) and the receipt of direct payments (from the first pillar of the Common Agricultural Policy) (Ahearn et al., 2018; Rocchi et al., 2019; Uematsu & Mishra, 2016). SFSC farmers are more likely to rely on family labor (Ahearn et al., 2018; Darolt et al., 2016; Kacz et al., 2019; Rocchi et al., 2019; Salvatore Tudisca et al., 2014) and non-agricultural diversification activities (e.g. equestrian activities) (A. Corsi et al., 2018; Darolt et al., 2016; Park et al., 2018; Rocchi et al., 2019).

1.3.3.3 Territorial characteristics

SFSC are further developed in wealthier areas with a more highly educated population (Bonanno, Berning, & Etemadnia, 2017; A. Bruce & Som Castellano, 2016; Connolly & Klaiber, 2015; S. Corsi & Mazzocchi, 2019; Dong et al., 2019; Hruška et al., 2020; Mazzocchi et al., 2020; Timmons & Wang, 2010). SFSC are mainly shopping places for affluent consumers with greater willingness to pay and skills for accessing fresh and high quality food products. Only one study

finds that farmer involvement in SFSC rises with the poverty rate (Ahearn et al., 2018). There is mixed evidence on the population age effect, with some studies reporting a positive effect (S. Corsi & Mazzocchi, 2019; Mazzocchi et al., 2020) while others report the contrary (Bonanno et al., 2017; Connolly & Klaiber, 2015).

Urban areas offer better conditions for SFSC development by offering opportunities to reach more consumers with higher purchasing power and skills (Ahearn et al., 2018; Bonanno et al., 2017; Connolly & Klaiber, 2015; A. Corsi et al., 2018; Dong et al., 2019; Hruška et al., 2020, 2020; Ilbery et al., 2006; Mazzocchi et al., 2020; Park et al., 2018; Pölling & Mergenthaler, 2017; Rocchi et al., 2019; Timmons & Wang, 2010). However, a few studies report a negative effect of population density due to a lack of available land and the maturity of local markets in many urban areas (S. Corsi & Mazzocchi, 2019; Plakias et al., 2020). Hence, urbanization leads to an increase of SFSC entrants if the initial population is small, where farmland is more available and market opportunities are increasing along with population (Bonanno et al., 2017; Connolly & Klaiber, 2015; S. Corsi & Mazzocchi, 2019).

SFSC participation is higher in places where mainstream supply chains (Bonanno et al., 2017; Dong et al., 2019; Mazzocchi et al., 2020) and SFSC (Ahearn et al., 2018; Bonanno et al., 2017; Connolly & Klaiber, 2015; Rocchi et al., 2019) are further developed but far from market saturation (Bonanno et al., 2017; Rocchi et al., 2019).

1.3.4 Barriers

There are many factors limiting the participation of farmers in SFSC. Farmers engaged in SFSC have difficulties ensuring a consistent supply based on a regular quantity and variety of food products owing to seasonality, consumer expectations and a lack of production diversity and capacity (Abate, 2008; Bateman, Engel, & Meinen, 2014; Eriksen & Sundbo, 2015; Griffin & Frongillo, 2003; Kupke & Page, 2015; Lea et al., 2006; Oberholtzer, Hanson, Brust, Dimitri, & Richman, 2012; O'Donovan, Quinlan, & Barry, 2012; Oglethorpe & Heron, 2013; Plakias et al., 2020; Rikkonen, Kotro, Koistinen, Penttilä, & Kauriinoja, 2013; Thompson et al., 2014). Their

production is challenged by weather conditions, crop losses, higher production cost and a lower productivity (Cerrada-Serra, Colombo, Ortiz-Miranda, & Grando, 2018; Fleury et al., 2016; B. B. R. Jablonski & Schmit, 2016; Mundler & Jean-Gagnon, 2020; Plank, Hafner, & Stotten, 2020; Plank et al., 2020).

SFSC are characterized by significant time and labor requirements due to additional tasks (e.g. processing, distribution; marketing and sale) and labor intensive methods of production (e.g. organic/agro-ecological production) (Aubry & Kebir, 2013; Bermond et al., 2019; A. Bruce & Som Castellano, 2016; Doernberg, Zasada, Bruszewska, Skoczowski, & Piorr, 2016; Lea et al., 2006; Möllers & Bîrhală, 2014; Mundler & Jean-Gagnon, 2020; Rikkonen et al., 2013; Rucabado-Palomar & Cuéllar-Padilla, 2020; Visser et al., 2013). Farmers have challenges in finding labor and specific skills because agriculture is not appealing and offers low wages (Aubry and Kebir, 2013; Griffin and Frongillo, 2003; Lea et al., 2006; Oglethorpe and Heron, 2013) while they have to rely on extra help (volunteers, family, …) (Bruce and Som Castellano, 2016; Kupke and Page, 2015). In addition, they are also concerned about their lack of experience with entrepreneurship and marketing (Drottberger et al., 2021; Fleury et al., 2016; Lea et al., 2006; Rucabado-Palomar & Cuéllar-Padilla, 2020; Syrovátková, Hrabák, & Spilková, 2014).

Farmers are also constrained from participating in SFSC by the lack of processing, storage and distribution infrastructure or equipment (Braun, Rombach, Häring, & Bitsch, 2018; Cerrada-Serra et al., 2018; Doernberg et al., 2016; Eriksen & Sundbo, 2015; Heiss, Sevoian, Conner, & Berlin, 2015; Mohammad, Yu, Neal, Gibson, & Sirsat, 2020; Plank et al., 2020; Ross, 2006; Rucabado-Palomar & Cuéllar-Padilla, 2020; Thompson et al., 2014; Visser et al., 2013; Yacamán Ochoa, Matarán, Olmo, López, & Fuentes-Guerra, 2019) and a lack of adequate land due to high land prices resulting mainly from urbanization (Abate, 2008; Aubry & Kebir, 2013; Cerrada-Serra et al., 2018; Doernberg et al., 2016; Horst & Gwin, 2018; Ross, 2006). They face financial and capital constraints in starting up or expanding their business including difficulties in accessing credit due to a lack of collateral or getting access to public aid mostly devoted to commodity crop growers (Cerrada-Serra et al., 2018; Doernberg et al., 2016; O'Donovan et al., 2012; Rikkonen et al., 2013;

Ross, 2006). In addition, they face logistic barriers linked to the financial cost and time of delivering small quantities over multiple delivery points (Braun et al., 2018; A. Bruce & Som Castellano, 2016; Eriksen & Sundbo, 2015; Jarosz, 2008; Lea et al., 2006; Matts et al., 2016; Milestad, Kummer, & Hirner, 2017; Rikkonen et al., 2013; Rucabado-Palomar & Cuéllar-Padilla, 2020; Yacamán Ochoa et al., 2019).

Farmers who participate in SFSC receive prices that do not always cover their costs due to price sensitive customers (Bateman et al., 2014; D. S. Conner, Sevoian, Heiss, & Berlin, 2014; Fleury et al., 2016; Heiss et al., 2015; Matts et al., 2016; Mundler & Jean-Gagnon, 2020; Oberholtzer et al., 2012; Oglethorpe & Heron, 2013; Paul, 2019). In addition, SFSC have a limited customer base such that farmers are constrained to combine many alternative channels, thereby increasing their workload (A. Bruce & Som Castellano, 2016; Doernberg et al., 2016; Möllers & Bîrhală, 2014; Oglethorpe & Heron, 2013; Paul, 2019; Rikkonen et al., 2013; Rucabado-Palomar & Cuéllar-Padilla, 2020). Low sales volume is the result of a lack of interest in local food (Baldy, 2019; Kupke & Page, 2015; Lea et al., 2006; Plank et al., 2020; Yacamán Ochoa et al., 2019) and because SFSC are most of the time not based on a "one stop shop" model (Oglethorpe & Heron, 2013).

Farmers who participate in SFSC have to deal with high membership fees required to participate in certain SFSC (e.g. FM) (Griffin & Frongillo, 2003; Kupke & Page, 2015; Oglethorpe & Heron, 2013), institutional issues (e.g. unclear legal and tax situation, legal form of the work, burdensome bureaucracy, etc.), packaging and contract requirements (Bateman et al., 2014; Matts et al., 2016; Plakias et al., 2020), as well as regulatory barriers (e.g. food safety and management standards) with inconsistent guidelines requiring high cost and time for their implementation (Baldy, 2019; Bateman et al., 2014; Kupke & Page, 2015; Laforge, Anderson, & McLachlan, 2017; Mohammad et al., 2020; O'Donovan et al., 2012; Plakias et al., 2020; Rikkonen et al., 2013; Thompson et al., 2014).

Farmers engaged in SFSC struggle to compete with large actors in mainstream supply chains, selling similar products at a lower price and not valuing social or environmental goals

(Abate, 2008; Baldy, 2019; Cleveland et al., 2014; Fleury et al., 2016; Galt, 2013; Galt, Bradley, Christensen, Kim, & Lobo, 2016; Griffin & Frongillo, 2003; Jarosz, 2008; Paul, 2019). They often find it difficult to cooperate with other farmers because cooperation can be time consuming or because economic interests may be poorly aligned (Eriksen & Sundbo, 2015; Griffin & Frongillo, 2003; O'Donovan et al., 2012; Yacamán Ochoa et al., 2019). They are also constrained by the lack of or inadequate support from organizational structures (e.g. cooperatives) and governments (Baldy, 2019; Cleveland et al., 2014; Drottberger et al., 2021; Laforge et al., 2017; Lea et al., 2006; Ross, 2006; Yacamán Ochoa et al., 2019).

1.3.5 Economic performance

Most of the studies show that farmers involved in SFSC are more viable or have better economic performance than they would in conventional supply chains. When involved in SFSC, they benefit from a price premium with a lower variability/uncertainty and capture the overall margin by eliminating intermediaries (Alonso Ugaglia, Del'homme, Lemarié-Boutry, & Zahm, 2020; Bauman, Thilmany, & Jablonski, 2018; Brekken et al., 2019; Broderick, Wright, & Kristiansen, 2011; Flores & Villalobos, 2018; Galt, 2013; Galt et al., 2012; Govindasamy, Hossain, & Adelaja, 1999; Govindasamy, Italia, Zurbriggen, & Hossain, 2003; Hu & Shieh, 2015; Hunt, 2007; B. B. R. Jablonski, Bauman, & Thilmany, 2020; Jablonski, Sullins, & Thilmany, 2019; Kim, Curtis, & Yeager, 2014; Morckel, 2018; Morel, Cristobal, & Léger, 2017; Mundler & Jean-Gagnon, 2020; Paul, 2019; Richard, Chevallier, Dellier, & Lagarde, 2014; Schmit, Jablonski, & Laughton, 2019; Sroka, Pölling, & Mergenthaler, 2019; S. Tudisca, Trapani, Sgroi, & Testa, 2015; Salvatore Tudisca et al., 2014; Verhaegen & Van Huylenbroeck, 2001).

By contrast, studies that find a negative impact of SFSC participation on farmers' income and sales highlight poor production performance resulting from limited economies of scale (Clark, 2020; Hardesty & Leff, 2010; Hu & Shieh, 2015; Khanal, Mishra, & Honey, 2018; Lohr & Park, 2010; Mundler & Laughrea, 2016; Park, 2015; Park & Lohr, 2010; Park et al., 2014, 2018; Silva et al., 2015; Uematsu & Mishra, 2016) or a non-significant effect (Bauman, Thilmany, & Jablonski,

2019; Chen et al., 2019). In addition, farmers have limited sales volume and receive low prices not covering their higher production and commercialization costs (e.g. significant labor, packaging and transportation expenses) but also transaction costs (e.g. information, negotiation and control costs). Some argue that farmers also have lower incentives for high profitability because they rely on other sources of income (non-agricultural work) (Mundler & Laughrea, 2016) and display non-economic motivations (Galt, 2013).

SFSC economic performance is also influenced by characteristics of the farmers, farms and the area where the farms are located. Most of the studies show that farmers are more likely to achieve higher economic performance with an increase of their acreage (Bauman et al., 2019; Khanal et al., 2018; Mundler & Jean-Gagnon, 2020; Park, 2015; Park & Lohr, 2010; Park et al., 2014, 2018; Uematsu & Mishra, 2016) and labor force (Bauman et al., 2018; Galt, 2013; Hunt, 2007; Park, 2015; Park & Lohr, 2010; Park et al., 2014, 2018). However, results of two studies show that larger farms are less likely to benefit from the adoption of SFSC (Ahearn et al., 2018; Detre et al., 2011). Better economic performance is also obtained by farmers with a higher percentage of leased land (Bauman et al., 2018, 2019; Galt, 2013; Lohr & Park, 2010; Uematsu & Mishra, 2016).

Farmers realize higher returns and sales when producing high-value crops (Bauman et al., 2018, 2019; Detre et al., 2011; Hunt, 2007; Uematsu & Mishra, 2016), as well as engaging in organic or environmental friendly practices that command a price premium (Ahearn et al., 2018; Chen et al., 2019; Detre et al., 2011; Govindasamy et al., 2003; Mundler & Laughrea, 2016; Sroka et al., 2019). A few studies report lower net income from organic production owing to higher production costs (C. Brown et al., 2007; Lohr & Park, 2010). There is mixed evidence on the effect of selling value added-products and increasing the number of varieties grown. More diversified production helps farmers to enhance their sales and to cope with production risks (C. Brown et al., 2007; Chen et al., 2019; Khanal et al., 2018), but they also lose benefits from economies of scale (Ahearn et al., 2018; Flores & Villalobos, 2018; B. Jablonski, Thilmany, Sullins, & Curtis, 2017). Although retailing value added-products may lead to an increase of farm revenue and help farmers manage risks (Govindasamy et al., 1999; B. Jablonski et al., 2017), higher costs incurred from requiring

more inputs can also result in insufficient or nil margins (Clark, 2020; Govindasamy et al., 2003; Mundler & Jean-Gagnon, 2020).

Proximity to urban centers offers farmers higher income by allowing them to reach more affluent customers (Bauman et al., 2018; C. Brown et al., 2007; Govindasamy et al., 1999; Hochuli & Schmid, 2021; B. B. R. Jablonski et al., 2020; B. Jablonski et al., 2017; Khanal et al., 2018; T. M. Schmit & Gómez, 2011; Sroka et al., 2019). Greater use of internet for collecting key information (e.g. on market conditions) enables farmers to achieve higher economic performance (Detre et al., 2011; Khanal et al., 2018; Park et al., 2018; Uematsu & Mishra, 2016). Marketing through traditional channels alongside SFSC generally improves income and sales (Bauman et al., 2018; Galt, 2013; B. B. R. Jablonski et al., 2020; Kim et al., 2014; Sroka et al., 2019; S. Tudisca et al., 2015). Studies reporting a negative (Govindasamy et al., 2003; Schmit & Gómez, 2011) or a non-significant effect of being involved in both SFSC and LFSC (B. Jablonski et al., 2017) rely on a self-assessment of their business situation. Regarding farmers' characteristics, better economic performance is achieved by full time farmers (C. Brown et al., 2007; Chen et al., 2019; Khanal et al., 2018; Park & Lohr, 2010; Park et al., 2014; Schmit & Gómez, 2011; Uematsu & Mishra, 2016) with greater farming experience (Ahearn et al., 2018; Hunt, 2007; Park & Lohr, 2010; Uematsu & Mishra, 2016). However, Park (2015) finds the opposite effect of full time farming on economic performance. He argues that working off farm can reduce exposure for farmers to market risks and help them to develop their network and human capital for their agricultural operations.

Lastly, SFSC economic performance varies between the different SFSC types. Some report a negative impact only for participating in FM and CSA because they are exposed to higher competition (Galt et al., 2016; Silva et al., 2015; Uematsu & Mishra, 2016). By contrast, others find that CSA achieve highest income because they benefit from lower transport and labor requirement (Jablonski et al., 2019; LeRoux, Schmit, Roth, & Streeter, 2010). Govindasamy et al. (1999) report lowest financial performances for temporal market (e.g. stands) and pick-your-own operations since they are available only for certain periods of the year and for certain seasonal products.

1.4 Concluding discussion

1.4.1 Main conclusions

The present literature review supports the following major conclusions. First, both economic and non-economic motivations as well as a dissatisfaction with conventional channels, encourage farmers to produce for SFSC. However, it is difficult to determine a dominant motivation.

Relative to the broader farm population, younger, female and more educated farmers are more inclined to market through SFSC. Small farmers who grow more diversified high value crops and animal products with more environmental friendly methods (organic or not) are more likely to participate in SFSC. Farms that participate in SFSC rely less on production contracts and, in the EU, the receipt of CAP direct payments but more on family labor, diversification activities and making use of multiple distribution channels. In addition, opportunities associated with SFSC increase with variables characterizing the farmer contextual environment including population density, income and education level of the population and marketing channel development.

Third, many constraints hinder the development of SFSC. Farmers experience some difficulties during the production phase and struggle to ensure a consistent diversified food supply. They are constrained by high labor requirements, logistic barriers, and inadequate entrepreneurship and marketing skills. They lack processing, storage and distribution equipment, access to adequate land and resources to start up or expand their business. They sometimes receive insufficient prices from a limited customer base and must meet costly regulatory and institutional barriers, membership fees as well as packaging and contract requirements. They often struggle to compete with large actors in mainstream supply chains and receive an inadequate support from organizational structures (e.g. cooperatives) and governments.

Fourth, even though a majority of studies report a positive impact on economic performance associated with SFSC participation, it remains difficult to draw a conclusion on the effect of SFSC on farmers' income. SFSC enable farmers to capture a price premium and reduce intermediary costs but suffer from high production, marketing and transaction costs. In addition, the economic impact

varies as a function of the SFSC forms and the characteristics of the farmers, farms and the area where the farms are located.

1.4.2 Recommendations for future research

Although consumers' motivations have been widely investigated, few studies have looked at the farmers' side. The literature has identified economic and social benefits as the most salient motivations for participating in SFSC, but other motivations (e.g. political, personal and environmental) have been less thoroughly addressed. A few studies show that motivations can differ between the various SFSC forms as they provide different entrepreneurial experiences. Farmers prioritizing non-economic motivations will prefer CSA, farm-to-institution, intermediated local supply chains (e.g. food hub) (Schoolman et al., 2021) and social purchase groups (Migliore et al., 2014) to FM and on-farm retailing as they are better adapt to provide benefits to the community (Schoolman et al., 2021). By contrast, FM and on-farm retailing are considered as more "instrumentalist" local food market. Furthermore, opportunistic farmers prioritize on-farm retailing to FM (Tonner & Wilson, 2015) and display a lower commitment to FM in low income urban areas (Montri et al., 2020). Similarly, we find that FM are more represented in studies in which economic motivations are the main drivers for SFSC participation and CSA in studies showing prevailing social motivations (Table A1.7). Studies finding non-economic motivations as dominant rely mainly on qualitative methods (interviews and focus group discussion). By contrast, those emphasizing economic motivations are mainly focused on quantitative methods (Table A1.8). Using mixed methods for investigating farmers' motivations and better exploring their link with SFSC types is therefore another avenue for research.

There are cross-country differences with studies conducted in Europe reporting mainly dominant economic motivations as compared to North America (Table A1.9). In addition, the limited research finding prevailing social motivations in Europe is exclusively in North European countries (Sweden, Norway and Poland). Only one study investigating motivations and 19% of the studies in this review use representative samples. These results call future research to further

investigate motivations differences across countries (but also differences in terms of characteristics and economic impact) based on representative samples.

The link between farmer motivations and their characteristics has also received little research attention. Opportunist farmers mainly motivated by profit are more likely to be younger and male farmers (Oñederra-Aramendi et al., 2018), farming full time for their livelihood (A. B. Bruce, 2019; Montri et al., 2020) in specialized farms (Oñederra-Aramendi et al., 2018). Some studies find that small farms which are less competitive, are more inclined to be driven by economic motivations in order to survive (Demartini et al., 2017) while others find the opposite results (Matts et al., 2016). The presence of distinct pathways into SFSC with various farmers and farms' profiles linked to different motivations can be studied to better understand the range of motivations. Future research could thus further investigate the boundaries of these distinct pathways and focus on whether or not these motivations are realized and compatible in practice. To the best of our knowledge, only two studies investigate motivation compatibility and they show mixed evidences. Galt (2013) finds that farmers engaged in CSA achieve a lower income because profitability is often not a high priority for them relative to other values. Kessari et al. (2020) conclude that economic and social goals are compatible in FM.

A large number of studies draw conclusions on SFSC determinants from basic descriptive statistics, but most of them focus on only a few characteristics and so may suffer from the omission of important factors. For instance, very little consideration has been given to policy variables from different governance levels, which can be a powerful driver. Only a few studies shed light on the most important characteristics. Farms rather than farmers or territorial characteristics have been, so far, identified as the most important in explaining farmers' engagement in SFSC (A. Corsi et al., 2018; S. Corsi & Mazzocchi, 2019). Farming experience, off-farm labor decisions and the use of origin labels should be further explored because of a lack of consensus on their effect. Similarly, using organic methods is reported as a driver of SFSC participation in most of the studies, but several studies find the opposite result indicating that more research is needed.

Although our results highlight that SFSC participation is not a panacea for farm income issues, future research should examine in greater depth the labor requirements and transaction costs which are difficult to account for. Our results highlight that most studies make use of quantitative methods regarding the SFSC impact on farmers' income while qualitative analysis can be a valuable resource to provide more detailed results. A few studies using regression analysis methods account for selection bias explained by unobservable factors (e.g. farmers' motivations) correlated with SFSC participation and income. Both downward (Park & Lohr, 2010; Park et al., 2014) and upward (Park et al., 2018) bias are reported when selectivity corrections are neglected. By contrast, Lohr and Park (2010) find that the exogeneity assumption is not rejected. Downward bias (upward bias) in the SFSC choice indicates that farmers' earnings are overestimated (underestimated) with respect to a randomly chosen producer. Future research should therefore further explore unobservable factors enhancing farmer income through SFSC. The performance of farms differs within SFSC and between farming sectors and market areas. Future research will need to tackle this heterogeneity by further examining the factors – operator, farm, and location characteristics – that explain SFSC farms' returns. Based on our results, there is mixed evidence on the effect of value added-products and increasing the number of varieties grown on farmers' income are found. In addition, a few studies show negative effects of organic production on farm income contrary to expectations. Mixed results are also found regarding economic performances of the different SFSC types.

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1.6 Appendix

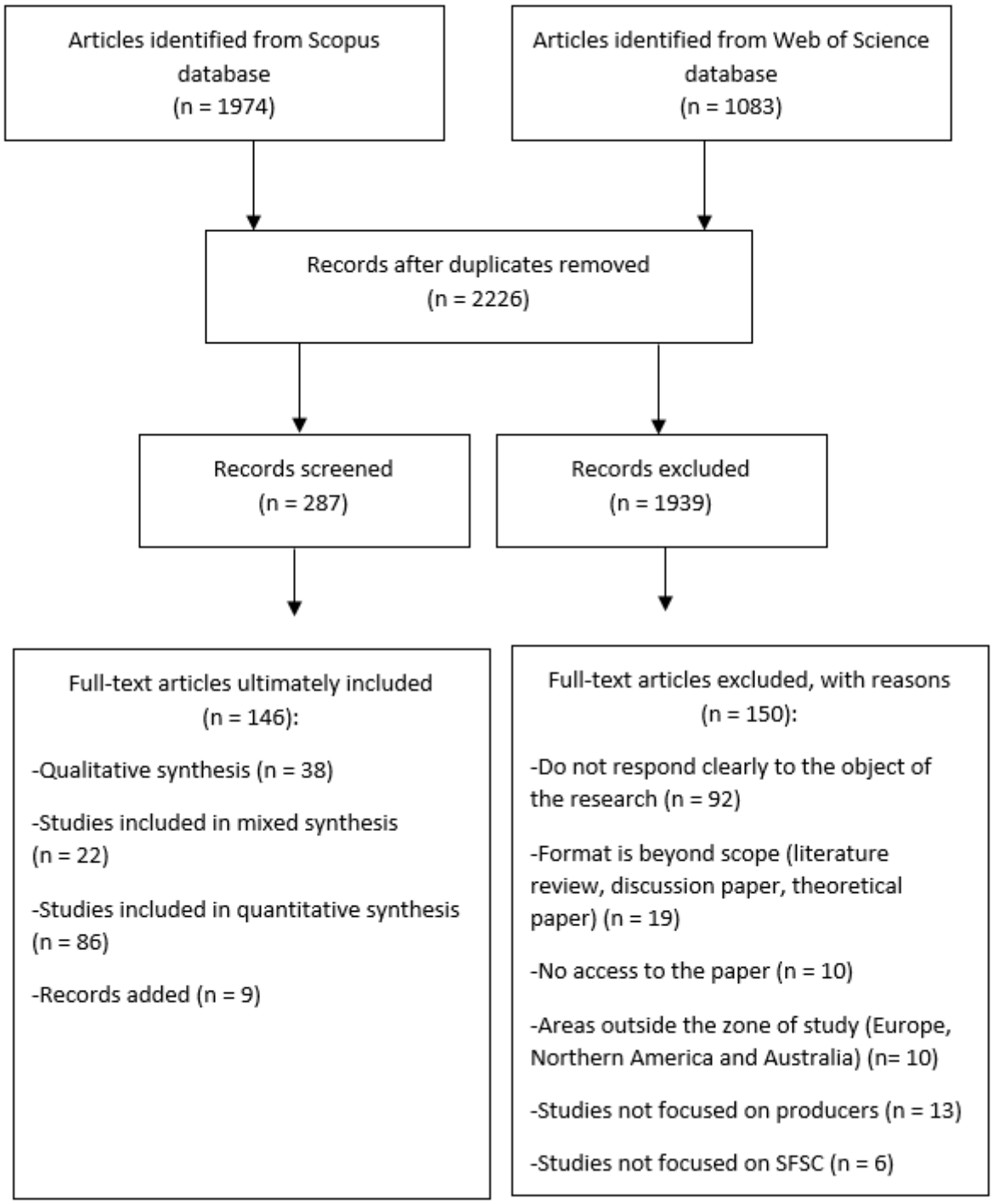

Figure A1.1. The PRISMA flow diagram

Table A1.1. Keywords

Supply chain keywords	Population keywords	Topic keywords
Local food	Farmer	Farmers' characteristics:
Local market	Producer	Feature
Local supply chain		Factor
Alternative food		Characteristic
Short food supply chain		Determinant
Direct marketing		Driver
Direct-to-consumer		Typology
Direct agricultural market		Type
Direct sales		Attribute
Direct selling		Farmers' motivations:
Shortened supply chain		Attitude
Direct Farm Marketing		Motivation
Community supported agriculture		Expectation
Farmers' market		Willingness
Farm-to-school		Incentive
Farm-to-institution		Reason
Innovative marketing		Goal
Locally grown		Barriers:
		Barrier
		Challenge
		Obstacle
		Constraint
		Difficulties
		Struggle
		Income Impact
		Profit
		Income
		Expenditure
		Earning
		Revenue
		Return
		Financial
		Performance
		Viability
		Wage

Table A1.2. The Population, Intervention, Comparison, Outcomes, and Study (PICOS) criteria.

Parameter	Inclusion criteria	Exclusion criteria
Population	Farmers	Articles outside the study zone (Europe, Northern America and Australia)
Intervention	Participation in local food system/short food supply chain	
Comparison	Not applicable	Not applicable
Outcomes	Characteristics, motivations, barriers and economic outcomes of farmers' involved in SFSC	Articles not responding clearly to the object of research and to its purpose Articles not targeting SFSC
Study design	Both quantitative and qualitative studies	Literature reviews, theses and dissertations, letters, book chapters, reports, authors' comments and other grey literature

Table A1.3. Supply chain abbreviations

Supply chain name	Abbreviation
Community supported agriculture	CSA
Farmers' market	FM
Farm-to-school	FTS
Farm-to-institution	FTI
Farm-to-Restaurant	FTR
Alternative food system	AFN
Direct marketing	DM
Local food system	LFS
Mid-tier supply chain	MTSC
Value-based supply chain	VBSC
Short food supply chain	SFSC
Solidarity purchase group	SPG
Alternative and local food supply chain	ALFSC
Conventional food supply chain	CFSC
Civic agriculture	CA
Local food hub	LFH

Table A1.4. Research articles based on quantitative approach.

	Author	Year	Setting	Supply chain	Farmer sample	Method	Key findings
1	Govindasamy et al.	(1999)	US	DM	Farmer survey (n= 455 with 79% of farms engaged in retailing). Not representative of general farm population (NR)	Logit model	DM utilization, particularly in the urban areas increases the likelihood of a farmer attaining the high income level. Greenhouse utilization, sales of value-added products, providing agrotourism activities and using garden center facilities increase farmers' profitability. Using organic production has an insignificant effect and temporal (e.g. stands) and pick-your-own type operations a negative effect on the likelihood of being in the high income level.
2	Gilg and Battershill.	(2000)	France	DM	Farmer survey (n =123 with 60 farms using direct selling and 63 mainstream supply chains). NR	Descriptive statistics	Farms using direct selling are more actively engaged in environmentally friendly farming practices with a lower usage of agrochemicals and relying more on organic farming practices. They have higher level of education with an experience in the non-agricultural world.
3	Verhaegen and Van Huylenbroeck.	(2001)	Belgium	Innovative marketing channels	Interviews with actors involved in 6 innovative marketing channels (direct selling (2), co-operatives (2) and labelled traditional marketing channels (2)). NR	Cost–benefit analysis	Farmers get higher revenues in all SFSC initiatives due to higher and less uncertain prices, compensating higher costs.
4	Govindasamy et al.	(2003)	US	FM	Farmer survey (n= 36) of farms retailing at FM. NR	Logit model	Older farmers, selling organic products and most of their production in FMs, in the growing stage of their business, are more likely to be satisfied with their profitability. Farm ownership structure and retailing value-added products does not affect farm profitability.
5	Ilbery et al.	(2006)	UK	LFS	Database on 548 producers, processords and/or retailers of local food. NR	Mapping Method	Horticulture (in particular), livestock (dairy and meat) and poultry tend to predominate in the local food activities. Proximity to urban centers and easy access to major roads favor local activities.
6	Åsebø et al.	(2007)	Norway	FM	Farmer survey (n=162) of farms marketing through FM. NR	Descriptive statistics	Producers consider how their food is produced to be significantly more important than where it is produced. They want to describe to customers how they grow their products and to establish a relationship with customers.
7	Brown et al.	(2007)	US	FM	Farmer survey (n= 236) of farms marketing through FM. NR	Ordinary least squares (OLS)	The number of products offered, distance traveled to market and number of weeks at market are positively related to farmers' income. Both part-time and retired producers received a lower income and have lower sales. Sales of organic products do not increase their income and sales.
8	Hunt	(2007)	US	FM	Farmer (n=65) and other vendors (n=16) survey of farms marketing through FM. NR	Cluster analysis and probit model	FM farmers are younger with a higher level of education and report farming as their full-time occupation.

							They report higher incomes than other farmers in Maine, and at least as high than other farmers nationally. Nearly all of them indicate that they have good future prospects on the market. Farmers' income increases with total hours worked (but with diminishing returns), experience and growing nursery or floriculture product types.
9	**Mireille.**	**(2009)**	**France**	**SFSC**	**Farmer survey (n =18 with farms involved in LFSC (1/3), SFSC (1/3) and combining the two marketing channels (1/3). Representative (R)**	**Descriptive statistics compared to national averages**	**Farms selling only through LFSC are specialized in an industrial way with large plots, on a very limited number of vegetables, cropped each year, with a focus on the main standard species in the region.** **Farms selling only through SFSC have crop species far more diversified following agro-ecological principles on smaller scales.** **Farms selling in mixed marketing channels have large surface areas and a diversified production.**
10	Hardesty and Leff.	(2010)	US	FM, CSA and wholesale	Farmer interviews (n = 3 with 1 farms engaged in FM, 1 in CSA and 1 in wholesale). NR	Cost and return analysis	Marketing costs are lower in wholesale markets and higher in FM. Higher price obtained by farmers are not pure profit due to significant labor costs associated with the additional activities in DM (e.g. marketing and transport).
11	LeRoux et al.	(2010)	US	FM, CSA, Farm stand and U-pick	Farmers' interviews (n= 4, with farms marketing trough FM (1), CSA (1), Farm stand (1) and U-pick (1). Farmer survey (n= 14) of farms selling local food. NR	Cost and return analysis	CSA is the top performing channel for profit, risk and marketing labor requirements. Wholesale channels ranked in the middle, primarily due to higher labor requirements. FMs have the lowest ranking because of a lack of profitability, higher labor requirement and lower sales volume. Marketing through CSA and wholesale market is the best option.
12	Park and Lohr.	(2010)	US	Local selling	Farmer survey (n=817) of farms selling local food. NR	Ordered probit model, Heckmans' method	Farmers with smaller acreage, more experience and using more internet tend to market the largest shares of their output in local markets. Organic producers and part time farmers focusing on local sales tend to achieve lower earned income. Acreage and labor, the number of years as a certified organic producer and the percentage of leased land have a positive effect on income earned.
13	Lohr and Park.	(2010)	US	Local selling	Farmer survey (n= 787) of farms engaged in local selling. NR	Stochastic production frontier models	Organic farmers involved in local sales achieve lower earnings.
14	**Timmons and Wang.**	**(2010)**	**US**	**DM**	**Census of Agriculture (CA) (2007) of farms in the 2,781 US counties. R**	**OLS model**	**Growing vegetables in smaller farms, located near cities in wealthy areas with more available land, increase direct food sales.**
15	Detre et al.	(2011)	US	DM	ARMS (2002, n =11,303 farms with 3% of the farmers in the sample using DM). R	Probit model	Farmers adopting direct marketing strategy (DMS) are younger, smaller and located near urban areas. They rely more on internet, organic practices and high-value crops. However, they are less likely to participate in production contracts. The production of high-value crops, the access to the internet and using organic method of production in conjunction with the adoption

							of a DMS increase gross sales. By contrast, large farms, with production contracts, specialized in cash grains have lower sales.
16	Schmit and Gómez.	(2011)	US	FM	Vendor survey in 27 FM (n=103) and market manager survey (n= 21). NR	Multinomial logit specification and ordinary least squares (OLS)	Full-time farmers are much more satisfied with their profit and have higher sales. Those selling in larger (with more vendors) and a limited number of FMs, with higher customer spending and located in areas with shorter average travel distances, are much more satisfied by their profit. Vendors selling arts and crafts, processed foods and beverages, or meat and dairy products are much less satisfied with their level of profitability. Fruits, vegetables, plants and nursery farmers have lower per customer sales, reflecting lower-priced for raw products.
17	**Uematsu and Mishra.**	**(2016)**	**US**	**DM**	**ARMS (2008, n = 4,629 farms). DM strategy includes Roadside stores (n =161), direct sales to local grocery stores, restaurants, or other retailers (n =153), FM (n = 118), Regional distributors (57) and CSA (12). R**	**Quantile regression**	**DM adoption has no significant impact on farm income due to additional labor requirement, learning cost, and other fixed costs associated with its adoption. However, direct marketing is a good risk management tool. Marketing through roadside stores, CSA and FM has a negative effect on farm income while farm stores and regional distributors have a positive effect. Diversification, farming as a primary occupation, farm size, farmers' education and experience, loans average interest rate, internet access, government subsidies, farm tenure and growing high value crops or producing dairy products affect positively gross farm income.**
18	Conner et al.	(2012)	US	FTS	Survey of farms associated with schools (n = 198). NR	Two-step cluster procedure	Farmers with stronger economic motivations are most likely to adopt distribution practices preferred or required by schools, followed by socially motivated and low engagement farmers. Socially motivated farmers will require more technical assistance to meet the economic realities of school markets.
19	Sage and Goldberger.	(2012)	US	DM	Farmer survey (n=670 with 149 farms engaged in DM). NR	Geographically Weighted Regression	Farmers involvement in direct marketing increases with organic farming practices and civic/green values while it decreases with dairy/livestock product types and market/industrial values (consummer demand, price premium for organic products, input costs).
20	Rikkonen et al.	(2013)	Finland	LFS	Local food enterprise survey (n = 42). NR	Descriptive statistics	The biggest obstacles to supply local food are linked to the lack of time, the legislative requirements, the distance from the market, the seasonality, attracting new customers, financing the business and finding adequate marketing channels and labor.
21	Kim et al.	(2014)	US	FM	Price data were collected, yields were provided by the USDA, cost of production are from various studies, Marketing costs are reported	Simulation model	FM offer the highest average return. However, price variability is greater for FM contrary to wholesale markets providing more stable revenues. Marketing 40% of output through FM and 60% through wholesale channels is the most attractive option for risk averse

					by Utahs' growers using a survey		producers, increasing average expected profit and decreasing variation in profit.
22	Park et al.	(2014)	US	DM	ARMS (2008, n = 340 with 10% of the farms in the sample use direct selling). NR	Multinomial logit (MNL) model with selectivity approach	Farmers using only DM report lower sales. Farm operators with a broader portfolio of marketing skills, using more hired labor and acreage and relying less on off-farm income display higher sales in direct marketing.
23	Migliore et al.	(2014)	Italy	FM, Box scheme, DM, SPG	Farmer interviews (n = 103) of farms engaged in CA. NR	Principal Component Analysis and Tobit model	Participation in the various forms of CA is associated to different farming attitudes. Participation in SPG is associated with the attitudes toward direct relationships with consumers and environmental sensitivity. By contrast, farmers participating in FM show the highest propensity toward profit maximization.
24	Syrovátková et al.	(2014)	Czechia	FM	Farm Structure Survey and Survey on Agricultural Production Methods (2010, n = not available). NR	Cartographic analysis	Lack of experience with private entrepreneurship and marketing is the main obstacle to broader involvement of farmers in FM.
25	Tudisca et al.	(2014)	Italy	SFSC (Direct sales, FM, e-commerce, farm shop, SPG and vending machines)	Farmer interviews (n=20) of farms marketing through AFN. NR	Descriptive statistics	More than half of the farmers adopting SFSC reports an improvement of their business economic performance. The main reason that leads farmers to adopt SFSC is to obtain higher farmer income followed by promoting the environmental sustainability of their farm.
26	Migliore et al.	(2015)	Italy	AFN (e.g. FM, box scheme, SPG)	Farmer interviews (n=103 with 51% of the farms engaged in FM, 31% in SPG and 18% in box scheme). NR	Principal composant analysis	There are two types of farmers participating in AFN. One type is oriented toward profit maximization and farm growth. The second type oriented towards satisfying social and environmental needs.
27	Connolly and Klaiber.	(2015)	US	Farm-stand, CSA, U-pick	Farmer database (N=4685) of farms participating in SFSC. NR	Ordered probit regression	An increase in the population size, land value, proportions of female, white and better educated residents lead to further direct-marketing operations. In addition, the number of farmers' markets increases direct-marketing operations while the number of wholesalers has no significant impact.
28	Silva et al.	(2015)	US	CSA, FTI, FTR, wholesale and FM	Farmer survey (n=135 with 60% of the respondents participate in wholesale markets, and less than half market to restaurants or institutions, with 47% using FM and more than 40% using CSA. NR	Multivariate probit model and ordered probit model	More educated farmers are more likely to sell into FM, CSA and restaurants/institutions and less into wholesale markets. Women farmers are more likely to sell through CSA and less into wholesale markets. As farm size increases, farmers are more likely to sell into wholesale market and less in FM. No evidences suggest that farmer age and experience affect market channel choices. Farmers selling into SFSC tend to be more likely dissatisfied with their profitability while those selling into wholesale markets and restaurants/institutions, are significantly more likely to be dissatisfied with their quality of life. Women are less likely to be satisfied with their profitability and quality of life. Farmers having farm

							debt or using a bank operating loans are less likely to feel satisfied with their profitability but more likely with their quality of life.
29	Hu and Shieh.	(2015)	US	Direct sales (« deliviery » to consumers, self-establishment of organic store, sales in private farms, market or on streets, production and marketing groups or cooperating with other farmers) Indirect sales (sales to middleman, production and marketing group, delivery companies, supermarket, organic specialty stores, restaurants and others)	Farmer interviews (n= 274) of farms participating in direct and indirect sales. NR	Analysis of variance	Organic farmers obtain higher sale growth through direct sales thanks to higher unit prices. Indirect sales provide higher gross profit rate, return on assets and return on sales than direct sales because of higher unit management and marketing costs on direct sales.
30	**Park.**	**(2015)**	**US**	**DM**	**ARMS (2008-2010, n = 5183 with 646 farms using DM and 4537 not DM). R**	**Recentered Influence Functions apply on the Unconditional quantile regression model**	**Involvement in DM is associated with a decrease in farm sales. Farmers who experience growth in off-farm income and expand their acreage and labor utilization are more capable to withstand sales declines.**
31	Kupke and Page.	(2015)	Australia	FM	Farmer survey (n=71 with 15.5% involved in DM). NR	Analysis of Variance, Principal components analysis (PCA)	Farmers are constrained by FM bureaucracy (e.g. form filling, volume of regulations), high labor requirement, FM costs (e.g. market rents, costs of outlay, competition), producing regularly enough volume and variety and consumers lack of interest for local food.
32	Tudisca et al.	(2015)	Italy	DM	Farmer survey (n=30) of farms adopting a SFSC strategy. NR	Descriptive statistics	Farmers report an increase of their profitability when using DM in conjunction with traditional channels (due to a lack of local demand).
33	Szabó and Juhász.	(2015)	Hungary	SFSC	Farmer survey (n= 202) of farms engaged in SFSC. NR	Factor, cluster and variance analysis, SERVQUAL model	Farmers participate in SFSC mostly to get higher income.

34	Matts et al.	(2016)	US	FTI	Farmer survey (n = 311) of farms participating in institutional markets. NR	Descriptive statistics	Farmers' motivations are driven largely by social values. Smaller farmers are significantly less likely to report economic factors and see more potential social value in FTI markets. FTI farmers report many challenges including timely payment, low prices, packaging consistency and delivery requirements.
35	**Aubert and Enjolras.**	**(2016)**	**France**	**SFSC**	**CA (n = 71 888 including both farms in SFSC and LFSC). R**	**Simultaneous Equation Regression**	**Farms selling through SFSC are more likely to implement environment-friendly practices.**
36	Farmer and Betz.	(2016)	US	DM	Farmer survey (n=190 including 40.5% of farms selling directly to consumers and 59.3% to institutions). NR	Logistic regression, Principal component analysis	DM participation increases with the farmers' educational level and decreases with acreage farmed and the family ties with the land. In addition, farmers using direct selling are less concerned with changes in technology, and are less dependent on external financing options. They are however more concerned about how their farming practices affected the environment and are more willing to try new methods.
37	Galt et al.	(2016)	US	CSA	Farmer survey (n= 111) of farms engaged in CSA. NR	Descriptive statistics and correlation analysis	Perceived competition in CSA is negatively correlated with farmers' profitability and satisfaction on various indicators of the social embeddedness. Farmers are therefore more likely to engage in self-exploitation, and worker exploitation.
38	Mundler and Laughrea.	(2016)	Canada	SFSC	Farmer survey (n=32) of farms engaged in SFSC. NR	Descriptive statistics compared to national averages	SFSC farmers are younger, more likely to have started their own farm, practice more certified organic agriculture on larger acreages. SFSC farmers have an operating profit margin (OPM) below that of all Quebec farmers, albeit strong variations between them. Organic farmers in SFSC have higher OPM than all Quebec farmers.
39	Rosalia Filippini et al.	(2016)	Italy	SFSC	Farmer interviews (n=55) of periurban farms. NR	Non-parametric tests	Farms exclusively in CFSC generally have higher land use intensity, but this is not the case for all the indicator values. Farm structure and individual farmers' characteristics are less related to market orientation.
40	Jablonski and Schmit.	(2016)	US	LFS	Two data sample based on farmers' interview (n=130 and n= 30) of farms with direct selling + ARMS (2008–2011) with 64 local farmers and 429 non local farmers representative of New York city. NR	Descriptive statistics	Expenditures are greatest on labor and other variable expense (hand tools, supplies, farm shop power equipment expense) due to the additional supply chain functions assumed by local food system participants.
41	Germeten and Hartmann	(2017)	Germany	School fruit scheme (farm-to-school)	School supplier survey (n=99 including 36 agricultural enterprises and farm shops). NR	Principal component analysis, Multivariate regression and ordered logit analyses	Motivations are multidimensional. Financial and entrepreneurial (competitive success) are the most important factors determining suppliers' intensity of participation. Non-economic determinants include the buyer–supplier relationship and the promotion of child nutrition.
42	Aggestam et al.	(2017)	Sweden	SFSC	Farmer survey (n=338) and interviews (n = 6) of farms engaged in SFSC. NR	Factor analyses, OLS regression	Positive attitude (e.g. increasing profits) is considered as the most important driver for the farmers' intention in scaling-up their SFSC business.

43	Demartini et al.	(2017)	Italy	SFSC (FM, CSA and farm shop)	Farmer questionnaire (n=150) of farms engaged in SFSC. NR	Principal component analysis	Motivations for farmers to participate in SFSC are mainly opportunistic even though they display social values.
44	Bonanno et al.	(2017)	US	FMs	CA (2007), data on farmers' market location are collected (1,833 zip codes). NR	Ordered probit and spatial ordered probit	An increase in the population may help the establishment of more FM if the initial population is small. Areas with younger, more highly educated individuals, smaller households but with a higher number of children support FM development. Complementary services such as grocery stores and drawing from a larger potential pool of farmers also enhance the location of FM. By contrast, the absence of farms and limitations in finding adequate space for establishing the market itself (i.e., housing density effects) constraint the development of FM.
45	Jablonski et al.	(2017)	US	DM	Farmer survey (n=100) with 63 engaged in DM. NR	Ordered probit model	Increasing the number of varieties grown affects negatively the income of farmers involved in DM. By contrast, being located in more urban areas, increasing the length of the production season and diversifying activities (e.g. selling fruits and value-added fruit products or adding services) increase farm profitability.
46	Morel et al.	(2017)	France	DM	Farmer interviews (n= 20) of farms engaged in DM. NR	Stochastic Modeling	Organic micro farms using direct selling could be economically viable depending on the level of income and workload accepted by farmers. Low-cost investment strategies based on self-built equipment and second-hand materials led to lower viability by increasing workload. The 9-months marketing strategy led to higher viability than the 12-months marketing strategy due to higher labor productivity in the former.
47	Pölling and Mergenthaler.	(2017)	Germany	DM	Farmer survey (n=123) with 39 engaged in DM. NR	Logistic regression	Larger farms conducting organic farming, high-value crop production or livestock breeding, located near cities, headed by higher educated farmers are more likely to implement direct sale arrangements.
48	Flores and Villalobos.	(2018)	US	DM	Yields used are from the litterature, the percentage of the total yield harvested through time and farmers, market prices are collected, data on precipitation and temperature are collected from weather stations	Mixed-integer programming model	Differences in net profits between Albuquerque, Phoenix and Yuna regions can be attributed to the difference in planting and harvesting magnitudes. In addition, the use of protective, yield-increasing technologies (greenhouse) and the concentration on more selected product varieties can increase the estimated yearly profitability of local production.
49	Benedek et al.	(2018)	Hungary	FM	Farmer survey (n=156) of farms engaged in FM and conventional markets. NR	Non parametric test and maximun likelihood estimation	FM farmers are younger and more educated. They have less farming experience and are less likely to have future plans in terms of investments and contracts with their chosen markets. In addition, they have bigger farm and more diversified productions.
50	Oñederra-Aramendi et al.	(2018)	Spain	FM	Representative interviews (n = 10), and farmer survey	Cluster Analysis	Farmers motivations are economical, but non-economic reasons exist such as social and cultural heritage. Motivations are related to the personal

					(n=176) of farms engaged in FM. NR		characteristics of each individual, such as gender and age.
51	**Ahearn et al.**	**(2018)**	**US**	**DM**	**ARMS (2009-2012, n = 36,517 with 3560 farms in DM).R**	**Two-stage Heckman approach**	**New entrant farmers having a spouse, with a woman as principal operator and a high speed internet are more likely to use DM while farmers' age has a non-significant effect.** **Farms growing organically more products are more likely to use DM. Large farms with a production or marketing contract and receiving government payments are less incline to market through DM.** **Farmers in or adjacent to a metropolitan county, in places with more FM and with a higher poverty rate, increase the likelihood of marketing through direct channels although the acres of fruits and vegetables production per capita in a county reduces this likelihood.** **Factors affecting gross cash farm income (GCFI), affect differently returns on farm assets (ROA, long-term financial outcomes). Being young and well-educated is positively related to GCFI while education level has a negative impact on ROA and age a non-significant effect. Being a beginning farmer is negatively related to GCFI but positively to ROA. Farm size and the number of workers' hours on the farm are positively related to GCFI although they have a negative impact on ROA. Participating in contracting and government programs and production diversification are positively associated with GCFI but negatively to ROA. Engaging in organic production does not have a significant impact on the GCFI but a positive impact on the ROA.**
52	**Bauman et al.**	**(2018)**	**US**	**DM**	**ARMS (2013, n= 17 474 farms with 1,013 selling local food). R**	**Descriptive statistics**	**Participation in direct and intermediated markets may allow farms of any scale of sales to be financially viable (ROA) but with a significant heterogeneity. Producers using different channels are not significantly different for the majority of the profits' quartiles. However, direct-to-consumer marketers among the top performing quartile have significantly lower ROA than the top performers using intermediated markets or both types of channels.** **Fruits and vegetables producers report the highest returns among the highest performing producers. Farms located in metro counties significantly outperform those in areas farther from populated centers. Farmers in the top quartile are the less indebted suggesting that leverage is detrimental to returns.**

53	**Park et al.**	**(2018)**	**US**	**DM**	**ARMS (2008-2010, n = 5,959 farmers with 234 farms using only direct to consumers, 157 using only direct to retailers and 180 using both direct to retailers and consumers). R**	**Multinomial treatment effect model**	**Female farmers located near the cities, using more internet and non-farm activities (e.g. agri-tourism activities) are the more likely to choose DM strategies. Direct to consumers only and both direct-to-consumers and retailers are associated with a decrease in farm sales. DM farmers using internet, more labor and expanding their acreage are able to limit the amount of sales decline. By contrast, DM female farmers face larger sales declines compared to male farmers while farm experience does not have a positive effect on sales.**
54	Charatsari et al.	(2018)	Greece	SFSC	Farmer survey (n = 144) of farm more or less willing to enter SFSC. NR	Binary statistics and hierarchical regression analysis	Willingness to participate in SFSC is higher in individuals who display increased levels of citizenship behavior, who feel accepted in intra-community collaboration networks and enjoy a sense of closeness to other community members. By contrast, self-perceived lack of communication and collaboration competencies diminishes this willingness.
55	**Corsi et al.**	**(2018)**	**Italy**	**On and off-farm direct sales**	**CA (58 304 farms) with 14% of farms selling directly on-farm and 8.1% off-farm. R**	**Probit model**	**Male and younger farmers, more educated, are more interested in direct selling, though this is not true for all types of farming. For example, male operators are more likely to engage in direct sales, when they grow grapes, while the opposite holds for horticulture. Mixed forms of farming, diversification activities and organic farming are more conductive to DM. By contrast, quality signals like protected designation of origin (PDO) or protected Geographical Indications (PGI) have a negative effect on direct sales. Farms in hilly or mountainous areas and higher population density within short distance to the farm make direct sales more likely. The proximity to commercial poles affect positively but to a minor degree off-fam sales.**
56	Filippini et al.	(2018)	Italy	LFS	Farmer survey (n=51) of peri urban farms. NR	Principal component analysis	Cattle farms are more connected to LFS and to origin labels, contrary to dairy farms, as well as, production involving cereals, industrial crops and vegetables. Larger farms with a wider range of products are less involved in LFS. The farms most connected to LFS rely more on origin than organic labels.
57	**Khanal et al.**	**(2018)**	**US**	**DM**	**ARMS survey (2012, n = 18,728 farmers) with 5.4% using direct selling. R**	**Unconditional quantile regression**	**Organic farmers using direct-selling have lower sales and income because the prices they receive are not enough to offset their significant labor transportation and packaging costs. Larger farming operations benefit the most of participating in certified organic food production. Male operators, having marketing contract and access to internet with a lower distance to the market have higher income and sales.**

							The effect of farm diversification is positive for the 25th and 35th quantile of sales, however, it is negative for the 50th and higher quantiles, indicating that smaller farms may benefit from farm diversification while larger farms may benefit more from specialization.
58	Morckel.	(2018)	US	FM	Farmer survey (n= 45) of farms engaged in FM. NR	Descriptive statistics	Relocating farmers' market to the city core improved farmers' profitability and their satisfaction. In addition, the spending patterns vary by day of the week (higher the Saturday than the weekday) and season (higher in the summer).
59	Andrei et al.	(2019)	Romania	SFSC	Farmer survey (n= 140) of farms engaged in SFSC. NR	Correlations between variables	SFSC participation is determined by the type of activity, the size of the farm (smaller) and the farmer level of education (more educated).
60	**Dong et al.**	**(2019)**	**US**	**CSA**	**CA (2007 and 2012, n= 4587 CSA farms) and the US Census Bureau (2005 and 2010). R**	**Tobit model**	**Small-scale farms primarily engaged in growing vegetables, melons, fruits and tree nut crops, and headed by younger and women operators whose primary occupation is farming, tend more to market products though CSA. The share of farms marketing through CSA is highly correlated with high-income households with more females, less seniors and less children.**
61	Yacamán Ochoa et al.	(2019)	Spain	SFSC	Farmer survey (n= 90) of peri urban farms. NR	Descriptive statistics	Farmers' involvement in SFSC is challenged by distribution costs, lack of interest from citizens in local food products, lack of organizational and physical structures, and associations in the periurban agricultural sector. In addition, large farms have difficulties to involve in SFSC due to their specialization and the lower amount of subsidies to change their business model.
62	Samoggia et al.	(2019)	US and Hungary (HU)	CSA	CSA farmer interviews from the US (n = 35) and HU (n=14). NR	Principal component analysis, and multiple multivariate linear regressions	Non-monetary benefits are the essential backbone of CSA farming, but the monetary benefits are to be ensured for CSA long-term perspective.
63	Schoolman.	(2019)	US	DM	US Census of Agriculture (1997 to 2012, between 2867 and 3118 farms using direct marketing over this period). NR	Two-way fixed effects model	The growth in local food systems in the US (measured as an increase in the total value of direct market sales) is strongly associated with declines in spending on agricultural chemicals even though the magnitude of this relationship dwindled over the next 15 years.
64	Schmit et al.	(2019)	US	DM	Farmer sample (n= 67 with 47 farms using DM). NR	Means difference tests	Average sales, expenses, and margins per acre are not statistically different when comparing farmers with a majority of sales through FM and farmers with less or equal to 50% of farm sales from FM. Farmers selling exclusively through their own retail farm stores have strong sale performances with respect to farmers selling mostly through FM but no net margin differences are found. Farmers selling on-farm have higher total expenses, average sales per acre and net

							margin than farmers selling exclusively through intermediated market channels.
65	**Bermond et al.**	**(2019)**	**France**	**SFSC**	**CA (2010, 516 152 farms using both SFSC and LFSC). R**	**Descriptive statistics and Principal component analysis**	**A greater participation in organic SFSC is linked to a smaller size of farms and a focus on plant and animal products. Farmers involved in organic SFSC are relatively younger and more educated. Farms in transition toward organic production and involved in SFSC deal with a higher labor intensity.**
66	**Bauman et al.**	**(2019)**	**US**	**Direct-to-consumer and local sales from on-farm store, u-pick, roadside stands, CSAs and FM; local retail outlet such as a restaurant or grocery store; Regional distributor such as food hub; Local institutions such as school or hospital**	**ARMS (2013-2014, n= 44 536 with 2624 farms selling local food). R**	**Stochastic profit frontier model**	**Scale has the largest influence on efficiency (defined as the ratio of the observed profit of an individual producer to the maximum observed profit) although the choice of marketing channel does not significantly affect it. Management of variable expenses (not including labor), production enterprise specialty (fruits and vegetables) and land ownership (the proportion of land leased) also influence positively producer financial efficiency.**
67	Lurie and Brekken.	(2019)	US	LFSC	Producer survey (n= 153) of farms selling local food. NR	Descriptive statistics	Local producers are mainly motivated by economic, social, and environmental concerns related to their communities.
68	Brekken et al.	(2019)	US	Values-Based Supply Chain (VBSC) and DM	Farmer survey (n= 182) of farms engaged in VBSC. NR	TOA-MD Simulation	Results indicate that average total net economic impacts from VBSC participation are positive, but less than half of participants have a net economic benefit from participation. VBSC gains depend on the relative prices and costs of the marketing channel options. First, VBSC participation is unlikely to provide higher farm net returns in cases where farms have direct marketing options with higher prices offered. VBSC participation provides higher net returns when farms' alternative

							options fall in the conventional wholesale category by providing higher prices for similar cost of participation.
69	**Chen et al.**	**(2019)**	**US**	**DM**	**ARMS (2012, n= 14960 with 7.17% of farms adopting DM). R**	**Bivariate binary choice model**	**Farmers' adoption of organic farming reduces the probability of adopting DM, whereas DM does not have a significant effect on organic farming adoption. In addition, there is a peer effect for farmers' adoption of organic farming and direct marketing. Cash grain farms are less likely to adopt either organic farming or DM whereas high-value crop farms are more likely to adopt both practices. Dairy farms are less likely to choose DM while other animal farms are less likely to choose organic production. The use of a production contract or marketing decrease the probability of DM adoption. Young and female farmers are more likely to adopt both practices. Farmers' probability of choosing either method decreases first and then increases as the education level increases.**
70	Corsi et al.	(2019)	Italy	DM	CA (2010, n = 1 544 of farms using DM). NR	Ordinary Least Squares (OLS)	The number of small, organic and PDO farms are drivers of participation in direct sales. The average income and age of the population affect positively the participation of farmers in direct sales while the population density affects it negatively.
71	Jablonski et al.	(2019)	US	CSA, FM, farm stands	Farmer survey (n= 42 with 37 farms using DM). NR	Descriptive statistics	CSA have the highest marketing profit margin, followed by farm stands, FM, and other direct markets. CSA farmers have the lowest transport and labor requirement compared to all direct market channels. However, other DM strategies and farm stands performed better than CSA in terms of sales and marketing profit per hour of labor. In addition, weekly gross revenue is less for CSA than FM and farm stands due to the relatively smaller size of their farms.
72	Kacz et al.	(2019)	Hungary	CSA	Farmer survey (n=32) of CSA farms. NR	Descriptive statistics	Farmers' involved in CSA are relatively old, operating their farm since a long time, working mostly either on animal or plant products on their own land. Their employment of external labor is low and rely more on family members while most of the farmers use conventional methods of production rather than organic.
73	**Rocchi et al.**	**(2019)**	**Italy**	**DM**	**CA (about 1,653,000 farms with 270,579 farms using DM). R**	**Likelihood ratio test**	**Farms using information technology and non-agricultural activities, adopting organic farming, growing all product types except field crops, managed by men, with a larger share of family labor are more likely to use direct-selling. Farmers' age and education do not affect direct-selling decision while education has a positive impact when related only to agricultural studies.** **Small farms are more likely to choose direct selling except in perennial crop sectors (e.g. wine, olive) where larger farms have a higher probability.**

							Population density increases the adoption of direct selling contrary to the presence of touristic activities and subsidies from the second pillar of the CAP at the municipality level. **The presence of FM provides incentive to direct selling at a certain mass level contrary to SPGS with a positive impact for a small number of them.**
74	Sroka et al.	(2019)	Germany	DM	Farmer survey (n=199 with 56 using DM). NR	Classification and regression trees	Elements of successful strategies (in terms of business situation, development perspectives and succession) include tourism services and DM. Probability of achieving high success increases also with organic production. However, the success of these strategies is mainly dependent upon farms' location. The closer a farm is located to highly urbanized areas, the higher the probability of achieving success. Farms' size is an important factor of success for farms without adjustment strategies, in less populated areas, relying mainly on economies of scale.
75	Charatsari et al.	(2020)	Greece	SFSC	Farmer questionnaire (n= 106 with 33 participating in SFSC). NR	Descriptive and inferential statistics	Perceived competencies are more important in predicting willingness to participate in SFSC than citizenship behavior. The potential economic benefits of participation do not contribute to the variance in willingness to participate in SFSC.
76	Clark.	(2020)	US	On-farm selling	Case study on one farm. NR	Cost and return analysis	On-farm store costs are still greater than income after the six-year period following the store opening. The farm store lacks economy of scale to offset high production costs (labor and material costs) and has a low sale volume. High-cost is driven by the increasing importance of ready-to-eat prepared foods requiring more inputs and providing insufficient margins for covering costs of operations. In addition, raising prices to account for more expensive inputs is a challenge due to low income of household.
77	Hruška et al.	(2020)	Czechia	AFN (CSA, on farm sales - farm shops, farm-based hospitality, pick-your-own; off farm sales - FM, sales to retailers, farm direct deliveries, veg boxes)	Four state databases of AFN farms in 2014 (n = 38) and five in 2018 (n = 55). NR	Descriptive statistics and spatial analysis	Small farms located in urban or rural-urban areas growing animal, plant or mixed production have a greater potential for integrating AFN. Most of the farm use only one distribution channel (mainly farm shop).

78	Jablonski et al.	(2020)	US	SFSC (FM, roadside stands, and u-pick), Intermediated channels (direct to restaurants, institutions, or to regional aggregators)	USDA ARMS (2013–16 , n = 78,559 farms) of farms selling local or non-local food. R Samples include 73,191 (positive labor expenditure) and 26,694 (positive wage) producers without local sales and 3,899 (positive labor expenditure) and 1,569 (positive wage) producers with local food sales	Descriptive statistics	Producers with local sales have significantly higher wage compared to those without, especially for operations with intermediated-only or intermediated and direct sales, as opposed to direct-only sales. Wages are higher for local food producers in more urban locations.
79	Mazzocchi et al.	(2020)	Italy	DM	CA (2010, n = 1522 municipalities). NR	Ordinary Least Square model (OLS)	Farmers' involvement in SFSC is more important in municipalities with higher income, older populations, bigger retailers and lower in municipalities with a larger number of rural areas. Farmers' involvement increases when farms are smaller, organic, managed by women and producing vegetables or animal products.
80	Mohammad et al.	(2020)	US	FM	Manager survey (n= 38) and vendor survey (n=85) in FM. NR	Analysis of variance (ANOVA) and OLS regression	There is a gap between farmers' food safety knowledge and their implementation due to a lack of proper facilities and equipment, a lack of specific food safety guidelines for FM, the food standard implementation costs and the lack of benefits to their business (e.g. low amount of sales).
81	Mundler and Jean-Gagnon.	(2020)	Canada	SFSC	Farmer survey (n=32) of farms involved in SFSC. NR	Descriptive statistics compared to national averages	There is not a marketing channel with higher net revenue suggesting that economic performance depend more on how farmers organize their work and control marketing costs than on the types of distribution channels they use. SFSC farmers have a lower productivity when carrying out production-related tasks, but it is often compensated by higher productivity in downstream activities (processing and marketing). Farmers' net earnings are often low when compared to the amount of effort involved. They deal with labor-intensive work conditions and struggle to get markups offsetting incurred costs.
82	Plakias et al.	(2020)	US	DM	Farmer survey (n= 24,907 farms with a 57.5% response rate) of farms using DM. NR	Logit models	Although farms of all sizes use direct selling, the ones using only DM are smaller and produce mainly vegetables, fruits, nuts, livestock and animal products. Beginning farmers are more likely to sell directly to consumers and retail channels while more experience in direct selling increases the likelihood to sell trough intermediates in the long run.
83	Tessier et al.	(2021)	Belgium	DM	Farmer interviews (n=36 with 14 using DM). NR	Archetypal Analysis	Farmers involved in direct marketing adopt low-input, low-capital, but knowledge intensive farming model embedded within alternative commercial and social networks, seeking to become autonomous from regime institutions.

84	Pépin et al.	(2021)	France	SFSC	Farmer survey (n= 165 with 99 selling for the local markets). NR	Factor analysis of mixed data	Agroecological practices are more likely to be supported by SFSC.
85	**Hochuli et al.**	**(2021)**	**Switzerland**	**DM**	**Agroscope annually surveys (n = 3500 dairy farms with 1019 using DM). R**	**Descriptive statistics and non-parametric test**	**Farms with agritourist activities achieve the best results in terms of income and labor productivity in comparison with the direct marketing and specialization groups of farms. Dairy farms with a DM strategy have similar incomes compared to farms with milk specialization. However, they perform significantly worse than those with the specialization strategy in terms of labor productivity. DM farms in high altitude have lower incomes due to the naturally more difficult production conditions but also the lack of proximity to markets with a higher population density.**
86	Schoolman et al.	(2021)	US	SFSC (On-farm sales, FM, FTI, FTR, CSA, FH)	Farmer survey (n=698 with 80% of the farms using SFSC). NR	Logistic regression models	Farmers who prioritize civic engagement and community institutions are more incline to use CSA, FTI and intermediaries (e.g. FH). By contrast, civic motivations are not important for selling at FM and on farm shops. Local farmers display a lower sense of environmental responsibility but also less importance to productivist considerations when making farming decisions.

Table A1.5. Research articles based on a mixed method approach.

	Author	Year	Setting	Supply chain	Farmers' sample	Method	Key findings
1	Ross.	(2006)	US	SFSC (e.g. FMs, restaurants/local institutions, on-farm retail, pick your own, CSA)	Farmer interviews (n=31 with 87% selling directly to consumers). NR	Descriptive statistics	Farmers using SFSC are mainly driven by making a profit. Major barriers are a lack of farmland, difficulties to obtain start-up financing, lack of processing facilities, training, technical assistance and access to government farm credit programs.
2	Abate	(2008)	US	FM, CSA, FTI and FTR	Farmer survey (n =100 with 27% selling at FM, 15% in CSA, 47% at farm retail and roadside stand). NR	Descriptive statistics and interviews	Farmers involved in SFSC are constrained by a lack of farmland, diversify and year-round supply due to seasonality and suffer from competition with conventional channels.
3	Aubry and Kebir.	(2013)	France	On-farm selling, FM, pick-your-own farms, box scheme (e.g. AMAP), online sales, and direct deliveries to restaurants, canteens and supermarkets	Interviews with decision-makers (n= 8) and farmers engaged in SFSC (n= 62). NR	Descriptive statistics and interviews	Farmers tend to combine different types of supply chain, rather than specializing in only one. Farmers involved in SFSC face constraints such as a lack of land due to urbanization and high land price, a lack of labor (agriculture is not attractive) and the weakness of producers' collective organization supporting SFSC.

4	Auld et al.	(2009)	US	DM	Farmer survey (n=15) of farms selling local food. NR	Descriptive statistics and interviews	Small farms tend to produce a small crop volume, pushing them to primarily sell their produce directly to consumers in order to maximize profits.
5	Björklund et al.	(2009)	Sweden	FM, farmers' own markets, direct to local grocery stores, CSA, schools and restaurant and/or direct-to-consumers through internet	Farmer interviews (n= 6) of farms selling local food. NR	Descriptive statistics, and interviews	Farmers interacting directly with consumers have more diversified productions.
6	Oberholtzer et al.	(2012)	US	FTS	Farmer survey (n =120) of farms engaged in FTS. NR	Descriptive statistics and interviews	Farmers meet several barriers when supplying schools such as getting certification, low price, having a contact with school, school timing and distribution challenges (e.g., delivery to several different schools).
7	Galt et al.	(2012)	US	CSA	Farmer interviews (n=54) of farms engaged in CSA. NR	Statistic descriptives	CSA farmers are younger, well educated, relatively new in agriculture relying on off-farm jobs and include greater proportion of women than Californian and US agriculture. Farms are smaller, growing a large number of crops, relying mainly on agroecological methods with diverse land tenure arrangements. Regarding profitability, 54% of the respondents indicate that their CSA is profitable, 32% broke even and 15% operate at a loss.
8	Fielke and Bardsley.	(2013)	Australia	FM	Farmer survey (n= 41) of farms engaged in FM. NR	Non parametric techniques	Consumer feedback, community values and fun are the most important reasons for selling at FM indicating that benefits of FM to producers are primarily social.
9	Oglethorpe and Heron.	(2013)	UK	LFSC	Questionnaires, workshops and interviews (n= 23 food businesses involved in LFSC including producers, retailers, processors). NR	Questionnaire,work shop and interviews	Local farmers face constraints due to the scale and the nature of products (e.g. perishability, small production); financial aspects (e.g. unrealistic price offered, membership fees, low customer base); additional operational time requirements (e.g. : a lack of access to a "one stop shop"); institutional factors (e.g. difficulties to supply institution due to guaranteeing supply); supply chain relationships (face to face interaction can become a constraints when the retailers' team change); skills (e.g. difficulties to find skilled artisan) and certification, policy and regulatory

							factors (accreditation are more complex and onerous).
10	Wubben et al.	(2013)	Netherland	Farm shop, FM, Farm-to-restaurant, CSA, box scheme, broker)	Farmer interviews (n= 19) of farms involved in SFSC. NR	Descriptive statistics and interviews	Most of the SFSC farmers are motivated by increasing their profit. Producer-support and producer-consumer interaction are also reported as motivations.
11	Galt.	(2013)	US	CSA	Farmer interviews (n= 54) of farms engaged in CSA. NR	OLS model and interviews	Farmers' motivations are diverse, but tend toward moderate instrumentalism, such that earning an income is often not a high priority relative to other values. Even though the profit rate of some CSA farms is higher than for other market channels, for most CSA their return is very small or nonexistent. Most CSA farmers undervalue their own work in monetary terms resulting in self-exploitation. Farmers' social embeddedness enhances the farmers' sense of obligation to members to his economic detriment. Older farmers, with more workers, accessing land at below market-value and combining different channels achieve higher income.
12	Thompson et al.	(2014)	US	SFSC (FM, grocery stores, CSA, internet, FTR, distributors)	Farmer survey (n=18 with 16 farms selling in FM, 2 in grocery stores,3 in CSA, 1 on interned, 2 selling in restaurants and 6 selling to produce distributors). NR	Descriptive statistics and Focus group discussion	Farmers meet challenges to supply schools including a lack of information (e.g. about what products schools want) and access to value-added facilities, costly government regulation (e.g. safety norms), and difficulties to guarantee a consistent supply of food.
13	Richard et al.	(2014)	France	SFSC	Farmer survey (n = 507) of farms engaged in SFSC. NR	Descriptive statistics and interviews	Farmers in SFSC have an higher income and productivity despite their lower production level and land use.

14	Alkon and Vang.	(2016)	US	FM	Farmer interviews (n= 27) of farms engaged in FM. NR	Descriptive statistics and interviews	Farmers report access to profit as the primary motivation for attending FM though they are also interested in freshness, health, sustainability and community.
15	Darolt et al.	(2016)	France and Brazil	SFSC (producers' market, collective points of sale, consumers' association, home boxes, independent organic shops, shops belonging to consumers and producers cooperatives, distribution network, farm shops, restaurant, virtual shop)	Technical visits in different SFSC (n = 40) Interviews with farmers (n = 7) and specialists of institutions working with organic agriculture (n=7).NR	Technical visits and interviews	SFSC involve mainly family farms managed by neo-rural producers working in small sites and offering more diversified products. A diversification in terms of the activities in the farm (leisure, accommodation, educational programs, …) is also observed.
16	Filipini et al.	(2016)	Italy	ALFSC	Farmer interviews (n=55 with 10% of farms selling exclusively to SFSC and 47% to LFSC, 43% mixed both marketing channels). NR	Non-parametric test and interviews	Farmers involved in ALFSC have different strategies. Those with a passive strategy use their professional or personal bonds to commercialize a small share of their production in ALFSC. Those with an opportunistic strategy try to maximize their profits by marketing through both conventional food chains (CFC) already developed by their family and to take advantage from new local channels. Farmers with active strategy sell all of their production through ALFSC in order to benefit from more independence over product quality, destination and in farm management. Differences between farmers using passive and active strategies are mainly related to innovations' indicator in the production suggesting certain adaptation made by farmers. Opportunistic strategy farmers rely more on social and commercial networks when selling products in ALFSC. They provide more efforts to diversify their products and show greater entrepreneurship and dynamism (in terms of number of food chains and products). Grain and crops are specifically devoted to CFC for farmers using both passive and opportunistic strategies.

17	Hvitsand.	(2016)	Norway	CSA	CSA stakeholder interviews (n= 5). NR	Descriptive statistics and interviews	Norwegian CSA producers are motivated by a desire of a production and food system that safeguards aspects of environment, justice, health, participation and communication.
18	Laforge et al.	(2017)	US and Canada	DM	Interviews with farmers and ranchers (n= 51) and questionnaire to farmers (n = 169) engaged in DM. NR	Descriptive statistics and interviews	Farmers in DM have to face inconsistent enforcement of food safety regulation (unaffordable, time consuming, inconsistent, not adapted to small farmers) and a lack or inadequate government support (under-resourced, bureaucratic and adapted to export-oriented producers).
19	Leiper and Clarke-Sather.	(2017)	US	FM	Farmer interviews (n= 17) of farms engaged in FM. NR	Descriptive statistics and interviews	Social motivations exist in tandem with economic motivations but also personal, philosophical, or political motivations.
20	Albrecht and Smithers.	(2018)	Canada	FM, CSA, specialty stores, pre-order delivered or picked up, on-farm delivered or picked up	Farmer interviews (n = 17) of farms engaged in SFSC. NR	Descriptive statistics and interviews	Farmers' motivations stem from dissatisfaction with conventional farming systems. Motivations are rooted in self-interest, with farmers seeking more profitable and autonomous business opportunities. However, producers value also trust, reconnection with consumers while looking for playing an educational role.
21	Horst and Gwin.	(2018)	US	DM	Interviews with key informants (n=15), hosted three group discussions (n=25), and a survey of direct farmers (n=33). NR	Interviews, group discussion meetings and descriptive statistics	Land access is a challenge for direct farmers due to rising land prices relative to their incomes, a lack of appropriate land, and insecure leasing terms.
22	Sitaker et al.	(2020)	US	CSA and Farm Fresh Food Box (FFB)	FFB Farmer interviews (n=9) and retailers' interviews (n=12). NR	Descriptive statistics and interviews	The primary motivation to FFP participation is to address direct-to-consumer market saturation, expand their customer base and moving to a VBSC at a larger scale.

Table A1.6. Research articles based on a qualitative approach.

	Author	Year	Setting	Supply chain	Farmer sample	Method	Key findings

1	Andreatta and Wickliffe.	(2002)	US	FM	Farmer interviews (n=38) and focus groups (n = 31) of farms selling in FM. NR	In-depth interviews and focus groups	Farmers value FM both because they could get a better price than elsewhere and have interactions with consumers.
2	Griffin and Frongillo.	(2003)	US	FM	Farmer interviews (n= 14) of farms engaged in FM. NR	Interviews	Farmers' involvement in FM is a result of economic and social motivations. FM are viewed as attractive venues due to profitability and convenience, but also a place to socialize with customers and other vendors, in addition to receiving positive feedbacks on their produce. FM participation is challenged by the competition from large corporate farms and supermarkets, difficulties in finding and hiring labor, and managing high input costs, keeping up with changing customer tastes, farmers' uncooperativeness and increasing stall fees.
3	Lea et al.	(2006)	US	CSA	Farmer interviews (n=12) of farms engaged in CSA. NR	Interviews	Main benefits perceived by farmers are financial (e.g. obtaining a fair price) followed by the establishment of a reliable market and the ability to plan production accurately. CSA farmers deal with several concerns such as sharing the risk with consumers, the ability of members to perform the job, the seasonality, the logistics, the lack of government support and the time required for administrative and bookkeeping tasks.
4	Alkon.	(2008)	US	FM	Interviews with farmer market managers, vendors and regular customers (n = 35). NR	Observations and interviews	While farmers argue that their economic and sustainable priorities are compatible, they sometimes sacrifice the latter to maintain the former in order to sustain their livelihoods.
5	Jarosz.	(2008)	US	CSA and FM	Interviews with wholesalers (n = 1), farm suppliers (n = 2), farmers (n = 9), farmers' market managers (n = 3), food cooperative workers and executives (n = 3), food bank managers (n = 1), and representatives of nongovernmental organizations (n= 3). NR	Interviews	Farmers in DM face difficulties in sustaining their livelihood due to a lack of time to load, unload, display and sell their products in addition to the time dedicated to the production and the competition from the industrial production selling similar products at a lower price.

6	Cox et al.	(2008b)	UK	CSA	Interviews of farmer and manager engaged in CSA (n = 25). NR	Interviews	The only goal of the farmers is simply to make organic produce available to local people without increasing food miles. There are no social goals contrary to the motivations of CSA producers found in much of the literature.
7	Izumi et al.	(2010)	US	FTS	Farmer interviews (n=7) of farms engaged in FTS. NR	Interviews	Farmers sold their products to schools with the view to diversify their marketing strategies and to contribute to social benefits.
8	Milestad et al.	(2017)	Austria	Box scheme	Farmer interviews (n= 19) of farms engaged in local organic box Scheme. NR	Interviews and focus group discussion	Box scheme farmers value flexibility and not written and long term bidding contract. They perceived box scheme growth as undermining their relationship with them due to a loss of flexibility and spontaneity while the growth process faces logistical barriers in distributing products from high number of suppliers.
9	Broderick et al.	(2011)	Australia	Farm-to-restaurant, supermarket and food service distributors, FM, home delivery	Farmer interviews (n=6) of farms engaged in SFSC. NR	Interviews	Producer-driven marketing of branded meat improves their income by avoiding the variability in farm-gate prices experienced in the mainstream channels, capturing the marketing margin, gaining a premium, as well as, controlling various commercialization costs and negotiation costs.
10	Jarosz.	(2011)	US	CSA	Farmer interview (n=11) of farms engaged in CSA. NR	Interviews	CSA farmers' motivations are not primarily economic but encompass social relations, a land care ethic, changing their life-work in order to do something more meaningful, feeding people with food of good quality, seeing and knowing their customers with an educational commitment toward them and offering an alternative to commodified food.
11	O'Donovan et al.	(2012)	Ireland	FTS	Consultation with FTS farmer (n=15) and practitioners (n=18). NR	in-depth consultation process	Farmers meet regulatory (e.g. compliance cost), financial (e.g. costs, credit facilities and terms of payment), operational (e.g. purchasing, ordering, integration of processes and procedures) and quality and refinement issues (variety, quality). They emphasize the lack of unity between food stakeholders and challenges in moving towards co-operation rather than competition.
12	Visser et al.	(2013)	Netherland	LFS	Farmer interview (n = 5) of farms selling local food products. NR	Interviews	Farmers' involvement in LFS is motivated by getting higher prices. They are mainly constrained by a lack of time and distribution infrastructures increasing costs.
13	Bateman et al.	(2014)	US	FTS	Farmer interviews (n=10) of farms engaged in FTS programs. NR	Interviews	Farmers supplying canteens deal with constraints related to seasonality and planning ahead, lack of fair price and meeting processing, packaging, quality, quantity, and food safety requirements set by schools.
14	Cleveland et al.	(2014)	US	LFH	Interviews with key actors selling local	Interviews	Farmers choose local food hub (FH) even though it means not maximizing their profits in

					food (owner/manager n = 5, managers n= 3, farmers n= 6). NR		order to achieve their social goals of selling their food locally. They value the personal relationship they have with the FH owners and the idea of supporting their local food system. Fundamental challenge of local hubs is how to be economically viable within a system dominated by the goal of economic profit, while working for social and environmental goals that the mainstream channel doesn't value.
15	Conner et al.	(2014)	US	FTI, FTS	Interviews with FTI actors (farmers n = 5, distributors n=3, food hub n=2). NR	Interviews	Farmers value health, relationships, education and community and express concerns about receiving adequate prices for their produce even if they emphasize that price is not the main motivator.
16	Ngo and Brklacich.	(Ngo and Brklacich, 2014)	Canada	LFS	Farmer interviews (n = 9, NR) of farms selling local food. NR	Interviews	Farmers look for significant changes in their lives to ''re-connect to context—to the soil, to work (labor), to history, or to place and create a sense of community through the production of food".
17	Möllers and Bîrhală.	(2014)	Romania	CSA	Farmer interview (n=3) of farms participating in CSA. NR	Interviews and observations	Farmers' CSA participation is associated to an intensification of farm work while farmers report a lack of demand for local food products.
18	Heiss et al.	(2015)	US	FTI	Interviews with 19 supply chains actors involved in FTI (farmers (n=5), distributor (n=3), food hubs (n=2), institutional buyers (n=9)).NR	Interviews	The lack of infrastructures, positive relationships with buyers (e.g. to maintain sales and circumvent regulations) and the farms' viability (obtaining a price covering costs) are key factors that enable and constrain farmers in supplying FTI.
19	Tonner and Wilson.	(2015)	UK	FM and on-farm retailing	Farmer interviews (n= 14) of farms engaged in SFSC. NR	Interviews	Farmers are motivated initially by a dissatisfaction with traditional agri-food systems meaning that diversification is not necessarily motivated by entrepreneurial objectives. Once the need for diversification is unlocked, farmers face an entrepreneurial choice. Those with push motivations (such as risk reduction) choose non-entrepreneurial diversification in the form of FM, while those with pull motivations (such as business growth) exhibit characteristics of entrepreneurship and engage in entrepreneurial diversification in the form of on-farm retailing.
20	O'Kane and Wijaya	(2015)	Australia	FM	Farmer interviews (n=6) of farms engaged in SFSC. NR	Interviews	The main motivations to sell food at FM include producing food in ways that are consonant with farmers' philosophies and values ; enjoying interacting with their customers and receiving direct feedbacks;

							educating shoppers about alternative meanings of food quality; selling their products to a better price and growing food in an environmentally responsible way.
21	Doernberg et al.	(2016)	Germany	CSA	Interviews of CSA farmers (n= 4) and workshops from 6 CSA initiatives with farmers or participating consumers. NR	Interviews and workshops	CSA farmers deal with several constraints related to a lack of processing capacity, access to arable land and continually increasing land rents, high labor input requirement, financing difficulties, lack of consumers, unclear legal and tax situation, loss of identity and consumers' trusts following an involvement of alternative food producers in long supply chains.
22	Fleury et al.	(2016)	France and US	MTSC and VBFSC	Participant interviews in three MTSC s (France) and three VBFSC (US). NR	Interviews	Farmers are motivated by economic considerations to create new alternative because the mainstream channels do not provide acceptable economic returns. Their motivations also include social, ethical, and environmental values. Their participation is constrained by finding a trade-off between affordable consumer prices and fair price for farmers, higher production cost related to moderate size of these supply chains, difficulties in developing additional skills and the competition from actors in mainstream supply chains (requiring differentiation from these competitors).
23	Bruce and Som Castellano.	(2016)	US	FM, CSA, FTR and Farmers' cooperative	Farmer interviews (n=31) of farms engaged in SFSC. NR	Interviews compared to national averages	Farmers involved in AFN are younger, more educated and operate on smaller acreage. They are constrained by a lack of demand for local food. They rely mainly on older equipment and machinery, better suited to alternative production systems and their smaller scale. Their viability is endangered by a high labor requirement such that farmers must support their farm with non-farm income and by volunteering their time.
24	Eriksen and Sundbo.	(2015)	Denmark	LFS	Interviews in three local food networks (n =7). NR	Interviews	The development of local food networks is constrained by the shortfall of key intermediaries (e.g. abattoirs), the distance from the market, social aspects (e.g. conflicts, different economic interest, …), service/delivery features (non regular availability, limited supply) and the scaling up process which can endanger the alliance between food and place.
25	Braun et al.	(2018)	Germany	FM, box scheme, CSA, on-farm-selling and FTS	Interviews with SFSC farmers (n=5), wholesalers (n=3) and caterers buying local food (n=6). NR	Interviews	Organic farmers involved in DM and FTS deal with logistic barriers (e.g. transport time) and a lack of organic processing facilities while canteens depend heavily on preprocessed food.

26	Cerrada-Serra et al.	(2018)	Spain and Italy	CSA, box scheme, DM	Interviews in Valencia with SFSC producers (n=9), representatives of public bodies (n=5), consumers (n=4), social organizations (n=2) and professional Experts (n=2) Interviews in Rome with 14 SFSC producers, representatives of public bodies, technicians; NGOs and farmers' leaders. NR	Interviews and observations	Farmers involved in AFN deal with many challenges such as a limited land access due to urban development, a limited access to water, financial and capital constraints and organizational and technical problems.
27	Bruce et al.	(2019)	US	FM, CSA, FTR, farmers' cooperative	Farmer interviews (n=30) of farms engaged in AFN. NR	Interviews	Three types of famers involve in SFSC are identified. First, beginning farmers entering in agriculture as second career, relying on personal or family wealth, saving and non-farm income. Second, farmers leaving agriculture to pursue higher education and finally return later. They are more likely to inherit land but also social and professional networks on which they can rely on. The two first categories of farmers rely on non-farm income and have no family or complex connection to agriculture. They value health and environmental benefits, perceive farming as a meaningful vocation and lifestyle goal and are looking to change the food system by educating consumers and promoting new practices. Third, full-time farmers from several generations who enter in alternative agriculture by transitioning their farms from conventional to organic production systems. They are looking to ensure the economic viability of their farms while they value health concerns to avoid handling the pesticides and protect their kids from exposure.
28	Paul.	(2019)	US	CSA	Farmer interviews (n=16) of farms engaged in CSA. NR	Interviews	CSA can help farmers in earning a higher farm income and reduce risks, but average income earned on the farm is far from providing a living wage pushing farmers to work off the farm to get extra-income. Competition and low market price are the two main concerns of farmers in addition to a low level of sales.
29	Baldy.	(2019)	Germany	LFS	Interviews of local actors (n=26	Interviews	LFS development is constrained by hygiene regulation, competition with discount

					including 3 farmers). NR		structures, the lack of agency from local politicians and local councils, a lack of interest from the population.
30	Beingessner and Fletcher.	(2020)	Canada	CSA, FM, on-farm-selling), corporate marketing mechanisms and different arrangements (e.g., U-pick)	Farmer interview (n = 31 with 12 use DM, 12 rely on corporate marketing mechanisms, 4 are engaged in both, and others have different arrangements (e.g., U-pick berries) and focus group (n = 2). NR	Focus group discussions and interviews	Main motivations for localization are political and social, and stem from a critique of the dominant neoliberal agri-food system which goes against the idea that farmers are mainly motivated by economic factors.
31	Goszczyński and Wróblewski.	(2020)	Poland	AFN (e.g. urban open-air market, CSA and FM)	Local producer and consumer interviews (n=43). NR	In-depth interviews	Farmers seek to recreate a specific folk version of rural idyll and ensure individual safety of consumers and producers suggesting that non-economic motivations dominate.
32	Kessari et al.	(2020)	France	Collective farmer shops	Interviews with shop representatives, network leader and networks managers (n=16). NR	Interviews	The group with the best economic performance have the goal to educate urban consumers to choose the right product. Contrary to expectations, the group with the lowest economic performance have also the lowest social performance. The two last groups of farmers focus mainly on social and political goals (supporting an alternative system to foster social change and countering the conventional system) and achieve good and increasing economic performance.
33	Montri et al.	(2020)	US	FM	Farmer interviews (n=27) of farms engaged in FM. NR	Interviews	FM participation is motivated by farming as a primary livelihood strategy, a new business opportunity, a recreation, and a social mission. Farmers who joined FM in deprived areas to support their livelihoods are the most likely to drop out of these markets. Farmers who used the FM to explore a new business opportunity are less likely to drop out and those who farmed for recreation or for a social mission are most loyal and do not drop out.
34	Newsome.	(2020)	Australia	DM	Interviews of female producers engaged in DM (n=36). NR	Interviews	Female producers are seeking alternatives to hegemonic agriculture to resist the pressures of the cost-price squeeze and mitigate its negative environmental and social impacts.
35	Plank et al.	(2020)	Austria	CSA	Interviews (n=11) in 5 CSA. NR	Interviews	CSA farmers deal with institutional constraints (no consensus on the CSA legal form, legal organization of the work, inadequate grant application) ; social constraints (targeting only the upper and middle-class, the risk- sharing principle is not always applied, low consumers

							involvement) and material constraints (bad weather conditions, storage requirement, …)
36	Rucabado-Palomar and Cuéllar-Padilla.	(2020)	Spain	FM, on-farm-shop, online shop, home delivery, consumer groups, farming cooperatives, chain store, supermarket chains, restaurants)	Farmer interviews (n= 10) of farms e engaged in SFSC. NR	Interviews	SFSC farmers met logistical issues, lack of adequate resources, skills and time to take additional roles. The flexibility required at command planning can cause uncertainty and be risky. In addition, multichannel strategies need to be developed due to the lack of demand in SFSC increasing workload for the small producers.
37	Alonso Ugaglia et al.	(2020)	France	SFSC	Farmer interviews (n=48) of farms engaged in SFSC. NR	Interviews	Farmers report an improvement of their economic viability by selling through SFSC but generating an increase in the labor requirement.
38	Drottberger et al.	(2021)	Sweden	CSA, FM, Online marketplace, FTR, and on-farm shops)	Farmer interview (n=14) of farms e engaged in SFSC. NR	Interviews	Farmers are motivated by various personal, social, environmental, and economic factors. However, making money is secondary but necessary to their other goals: doing something they enjoy, opposing the globalized food system, being environmentally sustainable, raising awareness among consumers. Farmers lack business management, communication and practical skills and do not receive suitable financial support.

Table A1.7. SFSC types by prevailing farmer motivations

	FTI, FTS , FTR	FM	CSA	LFH	On-farm selling	U-pick	N
Economic motivation	0,25	0,66	0,33	0	0,33	0,08	20[5]
Non-economic motivation	0,30	0,4	0,60	0,10	0,2	0,1	17

Table A1.8. Method used to evaluate prevailing farmer motivations

	Quantitative	Qualitative	Mixed	N
Economic motivation	0.42	0.25	0.33	12
Non-economic motivation	0.18	0.64	0.18	11

Table A1.9. Prevailing farmer motivation by countries (in percentages)

	Economic Motivations	Non-economic motivations
North America	41,7	63.6
US	41.7	54.5
Canada	0	9.1
Australia	0	9.1
Europe	58,3	27.3
Netherland	16,7	0
Germany	8,3	0
Hungary	8,3	0
Italy	16,7	0
Spain	8,3	0
Sweden	0	9.1
Poland	0	9.1
Norway	0	9.1
Total	100	100
N	12	11

[5] The N for each row in this table is the number of studies of each type. The percentages for the rows reflect more than 100% to reflect that a single study can investigate different SFSC types (e.g. FM and CSA).

Chapter 2

The evolution and dynamics of farmers' engagement in direct-to-consumer channels

Abstract

In this study, we employ a mixed-Markov chain model to analyze the factors that influence the dynamics of farmers' involvement in direct-to-consumer (DTC) channels based on data from the French Agricultural Data Network. We also examine the historical evolution of participation in DTC channels using data from the French Agricultural Census. In contrast to studies indicating a rise in participation in DTC channels, our research shows consistently low and stable engagement in France since 1970, characterized by a significant hybridization with conventional supply chains. In addition, farmers involved in DTC channels have a high probability to decrease their involvement in direct sales over time or even completely abandon them. Factors such as increasing farmland size, declining farm profitability and the COVID-19 crisis all contribute to increasing this phenomenon.

Résumé

Dans cette étude, nous utilisons un modèle de chaîne de Markov mixte pour analyser les facteurs qui influencent la dynamique de participation des agriculteurs dans les circuits de vente directe (CVD) en utilisant les données du Réseau d'information comptable agricole français. Nous examinons également l'évolution historique de la participation aux CVD à l'aide des données du Recensement Agricole français. Contrairement aux études indiquant une augmentation de la participation aux CVD, notre recherche montre un engagement faible et stable en France depuis 1970, caractérisé par une hybridation significative avec les circuits conventionnels. En outre, les agriculteurs impliqués dans les CVD ont une forte probabilité, dans le temps, de diminuer leur engagement en ventes directes, voire de les abandonner complètement. Des facteurs tels que l'augmentation des surfaces agricoles, la baisse de la rentabilité des exploitations et la crise du COVID-19 contribuent à accroître cette probabilité.

2.1 Introduction

In the European Union, SFSC refer to supply chains with "a reduced number of intermediaries", generally involving no more than one intermediary from the producer to the consumer. In France, SFSC have been officially defined by the French Ministry of Agriculture as a marketing mode involving no more than one intermediary between the producer and the consumer. This encompasses both direct sales, through direct-to-consumer (DTC) channels such as farmers' markets, and sales via an intermediary, known as direct-to-retailer (DTR) channels, which could include outlets like canteens or supermarkets. Since several decades, there has been an increasing interest in SFSC among academia and policy-makers. Their development has been encouraged in the European Union (EU) by the European Agricultural Fund for Rural Development (EAFRD) devoting up to 10% of its expenditures to the promotion of food chain organization (Dwyer et al., 2016). Similarly, the U.S. Department of Agriculture invested US$501.5 millions over 5 years in diverse programs promoting local food production through the 2014 Farm Bill (Martinez, 2016). This growing interest in SFSC can be attributed to significant transformations within the food-retailing sector during the latter half of the 20th century as well as to the potential sustainable benefits of SFSC (Renting, Marsden, & Banks, 2003; Van Der Ploeg et al., 2000).

With increasing concentration in the food-retailing sector and the development of vertical integration, retailers have increasingly sought to minimize their costs by committing to a limited number of farmers capable of meeting high volumes and quality standards (Richards et al., 2013; Saitone & Sexton, 2017; Sexton, 2013). This has encouraged farmers to enhance production efficiency and volume, while increasing the difficulties of negotiating favorable prices and meeting retailers' requirements (Dries, Reardon, & Swinnen, 2004; Renting, Marsden, & Banks, 2003; Van Der Ploeg et al., 2000). Moreover, the increasing concentration within the food-retailing sector has coincided with the implementation of liberalized agricultural policies in post-1990 Europe, substituting price regulations with direct income support. This shift has led to amplified price volatility for farmers, linked more closely with global market prices (Swinnen, Olper, &

Vandevelde, 2021). In response to growing income pressures, many farmers have adopted innovative strategies such as establishing direct links with consumers to augment the value of their products (Saitone & Sexton, 2017; Van Der Ploeg et al., 2000). Farmers can get a higher price in SFSC because the tangible and intangible qualities of their products (e.g. authenticity, safety and trust) that allow them to command a price premium are more easily recognized when the link with the consumer is closer (Flaten et al., 2010; González-Azcárate, Cruz-Maceín, & Bardají, 2022).

On the demand side, increased public concerns about ecological, health, and animal welfare issues, along with growing distrust in conventionally produced food caused by numerous food scandals, have resulted in an increased consumer demand for higher product quality and differentiation (Renting, Marsden, & Banks, 2003; Saitone & Sexton, 2017; Sexton, 2013; Winter, 2003). Specifically, consumers have shown a notable interest in establishing direct links with farmers, based on transparency, trust and shared values, in order to reduce their concerns about conventionally produced food (Renting, Marsden, & Banks, 2003; Weatherell, Tregear, & Allinson, 2003; Winter, 2003). This shift in consumer expectations towards quality may have encouraged farmers to join SFSC.

In addition, the sustainable benefits of SFSC have been widely praised, especially for farmers, consumers, and rural communities (Enthoven & Van den Broeck, 2021; Kneafsey et al., 2013). SFSC have been argued to provide ecological benefits through decreased food miles and carbon emissions, while also favoring the adoption of sustainable farming practices. From a socio-economic perspective, it has been claimed that SFSC can contribute to improve farmers' income, economic development in rural areas, consumers' access to healthy food and social interactions around the growing and eating of food. However, very little quantitative evidence on the impacts of SFSC exists and some research even raises skepticism about their actual benefits (Tregear, 2011). In addition, as the local trap critic points out, there is a tendency among scholars to conflate the structural characteristics of SFSC with desirable outcomes and the motivations of their protagonists (Born & Purcell, 2006; Tregear, 2011). One reason is that there is a widely accepted hypothesis in the literature, which supposes that SFSC mainly attract farmers who give priority to non-economic

objectives, or that they inherently deliver more sustainable outcomes (Born & Purcell, 2006; Tregear, 2011). This therefore leads to romanticize the impact of SFSC on sustainability, and to question their real contribution to a more sustainable agri-food system (Born & Purcell, 2006; Tregear, 2011).

In addition, the highly heterogeneous nature of SFSC makes it difficult to analyze their sustainability. SFSC is a wide term covering a variety of marketing forms such as direct sales in farmers' stores or at farmers' markets, box schemes, internet selling etc. Some qualitative studies have also reported the existence of hybrid marketing strategy that combines both SFSC and conventional supply chains (Aubry & Kebir, 2013; Benedek, Fertő, & Molnár, 2018; Filippini et al., 2016; Sellitto, Vial, & Viegas, 2018; Zwart & Wertheim-Heck, 2021). In addition, qualitative research find that farms engaged in SFSC frequently shift in and out of conventional supply chains due to economic reasons (Ilbery & Maye, 2006; Ilbery et al., 2004; Ilbery & Maye, 2005a, 2005b).

However, research on the coexistence of SFSC with conventional supply chains and the dynamic nature of SFSC are from studies relying solely on case studies. The absence of solid quantitative evidence on the heterogeneous nature of SFSC may be attributed to researchers' inclination to view SFSC in binary opposition to conventional supply chains, and more specifically as a form of protest against the conventional system (Tregear, 2011). In contrast, the hybrid and dynamic nature of SFSC might suggest that farmers involved in SFSC do not inherently possess distinct motivations compared to those participating in conventional supply chains (Tregear, 2011). A hybrid marketing strategy might helps farmers engaged in SFSC to minimize their marketing risks by providing access to a larger and steadier customer base and facilitating the transfer of surplus products between different channels (Kim, Curtis, & Yeager, 2014; LeRoux et al., 2010; Uematsu, 2011). Another explanation might be the lack of detailed data on SFSC channels in agricultural statistics of European member states, especially on DTR channels (Enthoven & Van den Broeck, 2021). The majority of studies overlook the complex nature of SFSC and instead rely on a simplistic binary variable to designate farms engaged in SFSC when assessing their causal impact on sustainable factors (Enthoven & Van den Broeck, 2021). Neglecting the heterogeneity of

SFSC can be problematic, as the sustainability impact of SFSC involvement can vary based on the degree and the dynamics of participation in SFSC as well as the types of channels used.

In this study, we analysis the dynamics of participation in SFSC based on data from the French Agricultural Data Network. Our analysis focuses on DTC channels due to the lack of complete data on DTR channels in French Ministry of Agriculture databases. Participation in DTR channels is low in comparison to participation in DTC channels (AGRESTE, 2010, 2020). In addition, we examine how some economic factors influence the dynamics of farmers' involvement in DTC channels and, more specifically, the likelihood of a decrease in their involvement. Farmers involved in DTC channels face a number of problems that can lead them to decrease their direct sales or even abandon them (Argüelles, Anguelovski, & Sekulova, 2018; Stephenson, Lev, and Brewer, 2008). In particular, farmers may choose to reduce their reliance on DTC channels due to difficulties in scaling up, lack of economic returns and demand, and the negative impact short-term shocks such as the COVID-19 crisis.

A lack of profitability may prompt farmers highly engaged in DTC channels to choose a hybrid marketing approach, minimizing marketing risks (Kim, Curtis, & Yeager, 2014; Le Roux et al., 2010; Park & Lohr, 2007; Uematsu, 2011; Zhang, Qing, & Yu, 2019). They can express a desire to expand their operations, which could entail decreasing their direct sales because of various constraints hindering scalability in DTC channels (Aggestam, Fleiß, & Posch, 2017; Bruce and Castellano, 2017; Rucabado-Palomar & Cuéllar-Padilla, 2020). A decrease of average income near farm city might reduce demand for local food and constrain farmers to combine many marketing channels in order to have access to a broader customer base (Bruce & Castellano, 2017; Fleury et al., 2016; Heiss et al., 2015; Rucabado-Palomar & Cuéllar-Padilla, 2020). Finally, the COVID-19 crisis might have negatively affected participation in DTC channels due to partial closure of some places of DTC channels (Chiffoleau et al., 2021; T. J. Richards & Rickard, 2020; Thilmany et al., 2021).

This analysis relies on a Markov Chain Model (MCM), which has been extensively utilized in agricultural economics to examine the influence of time varying variables on changes in farming

structure. It has notably been employed to depict how farms transition across various size categories (Saint-Cyr, 2022; Zimmermann & Heckelei, 2012). Farming encompasses a diverse range of transition processes that underscore the variability in farmers' behaviors, influenced by both observable and unobservable characteristics of farms and farmers. We therefore employ a mixed-Markov chain model (M-MCM) in order to capture the influence of endogenous factors on the dynamics of participation in DTC channels at the farm level. This model partitions a farmer population into homogeneous types based on their transition patterns to account for heterogeneous behaviors, potentially driven by unobserved characteristics.

The paper is structured as follows. The following section provides descriptive statistics regarding trends in participation in DTC channels. Sections 2.3 and Section 2.4 introduce the data utilized in the empirical application and a literature review on the factors influencing the dynamics of participation in DTC channels. Section 2.5 provides a description of the modeling approach, while the results of the analysis are presented in Section 2.6 and discussed in Section 2.7.

2.2 Trends in DTC Channel Participation

Longitudinal data on participation in DTC channels are largely missing in most European countries. To the best of our knowledge, France and the United States (US) are both, the only developed countries that have collected data on direct sales since the 70s through Agriculture Census (AC). The US has tracked trends of direct sales over time by collecting data at stable five-year intervals (Enthoven & Van den Broeck, 2021; O'Hara & Benson, 2019). From 1978 to 2012, the proportion of farms engaged in DTC channels remained low and stable in the US, followed by a significant decline in this proportion between 2012 and 2017 (Enthoven & Van den Broeck, 2021; O'Hara & Benson, 2019)[6].

[6] Taking note that, until 2012, direct sales only considered unprocessed farm products like fresh fruit, fresh vegetables, milk, and eggs in the US Census of Agriculture. In 2017, the direct sales inquiry changed, requiring farms to report total sales that included both unprocessed farm products and value-added items processed on-farm, such as cider(O'Hara & Benson, 2019). The less restrictive nature of the direct sales inquiry in the US agricultural Census does not call into question the observed decline of participation in DTC channels between 2012 and 2017 in the US, but for vigilance with regard to how direct sales are defined when utilizing longitudinal databases.

In France, data on participation in DTC channels has been collected periodically through the Agricultural Census at roughly ten-year intervals since 1970. This allows for the longitudinal tracking of a binary variable indicating whether a farmer participates in DTC channels. Figure 2.1 presents the evolution of participation in DTC channels from 1970 to 2020 in both numbers and percentage of farms. The blue bar represents absolute count of farms involved in DTC channels, while the red line represents percentage of farms using DTC channels. The proportion of farms engaged in DTC channels is more stable than the absolute numbers, possibly due to the decline in the total number of farms in recent decades. The trends observed in both absolute numbers and proportion of farms involved in DTC channels reveal a peak in the 1980s, followed by a consistent decline until 2010. These findings contradict the majority of studies highlighting a rise in direct sales during this period, yet much of this research lacks quantitative evidence (Festing, 1998; Hinrichs, 2000; Kirwan, 2004; Powell, 1995; Renting, Marsden & Banks, 2003). Nevertheless, both trends highlight a recent increase in engagement with DTC channels between 2010 and 2020. This differs from the decrease in participation in DTC channels observed in the US between 2012 and 2017 (O'Hara & Benson, 2019).

It is uncertain whether this recent rise will continue over the long term or is it simply a temporary positive fluctuation. To address this question, we use the French Farm Accountancy Data Network (FADN), which contains around 7000 representative farms surveyed annually. It collects information on participation in DTC channels from 2006 to 2022 by incorporating a variable that differentiates farmers based on whether their direct sales (in value) account for less than 75%, more than 75% of their total sales, or none at all. Figure 2.2 presents the evolution of the percentage of farms participating in DTC channels from 2006 to 2022 based on FADN datasets. The blue line represents the trend of engagement in DTC channels across all levels of direct sales, while the red line pertains to those with over 75% of their total sales and the green line refers to those with less than 75% of their total sales in DTC channels. The majority of farms engaged in DTC channels have less than 75% of their overall sales through these channels. Therefore, a prevalent approach to participating in DTC channels is a hybrid strategy that combines DTC channels and conventional

supply chains. This result questions the oppositional conceptualization of DTC channels in the literature that solely regards it as a radical form of protest against the established mainstream system (Tregear, 2011). In line with the AC, there is an increase of participation in DTC channels observed from 2010 to 2020. Nonetheless, this increase is temporary, followed by a notable decrease in participation in the subsequent years of 2021 and 2022. The decline in direct sales primarily stems from a decrease in the farms selling less than 75% of their produce directly. This notable drop in engagement in DTC channels could potentially be attributed to the impact of the COVID-19 pandemic that occurred at that time.

Several studies have highlighted the considerable impact of the COVID-19 crisis on producers engaged in direct sales, despite their notable resilience capabilities (Thilmany et al., 2020, 2021). One potential explanation, as suggested by O'Hara & Benson (2016), could be the strong correlation between direct sales and economic cycles, attributed to their substantial dependence on affluent consumers. Nonetheless, it is important to note that the purchasing power of consumers in France remained steady throughout the COVID-19 period. Another possible factor could be the implementation of social distancing measures leading to the temporary closure face-to-face markets, like farmers' markets (Benedek et al., 2022; Chiffoleau et al., 2021; T. J. Richards & Rickard, 2020; Thilmany et al., 2021).

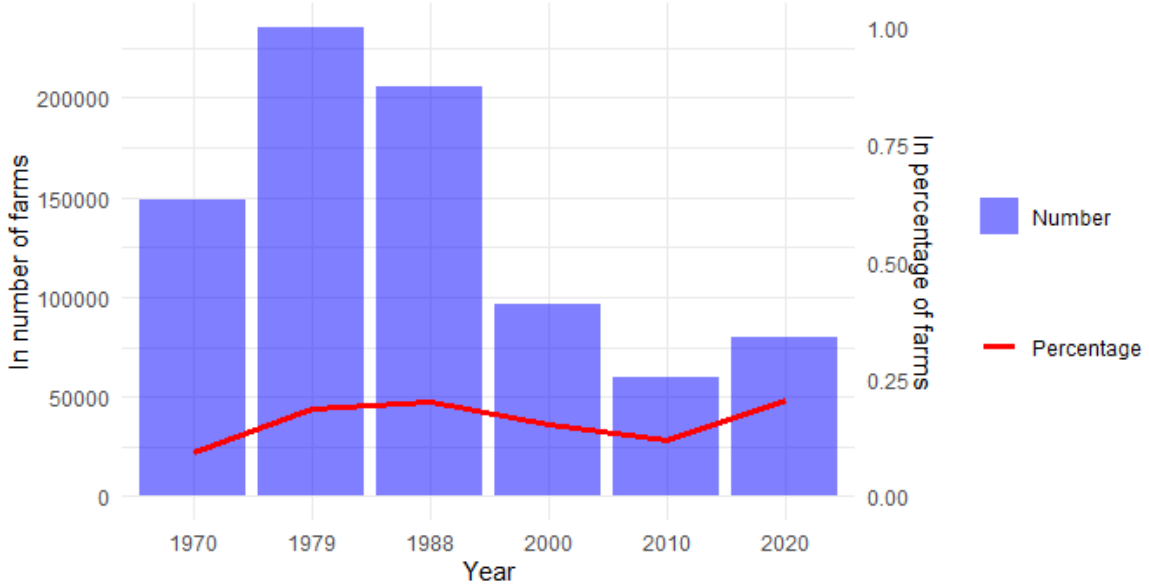

Figure 2.1. Evolution of DTC channels participation from 1970 to 2020 in both numbers and percentage of farms. Source: 1970-2020 French Agricultural Census

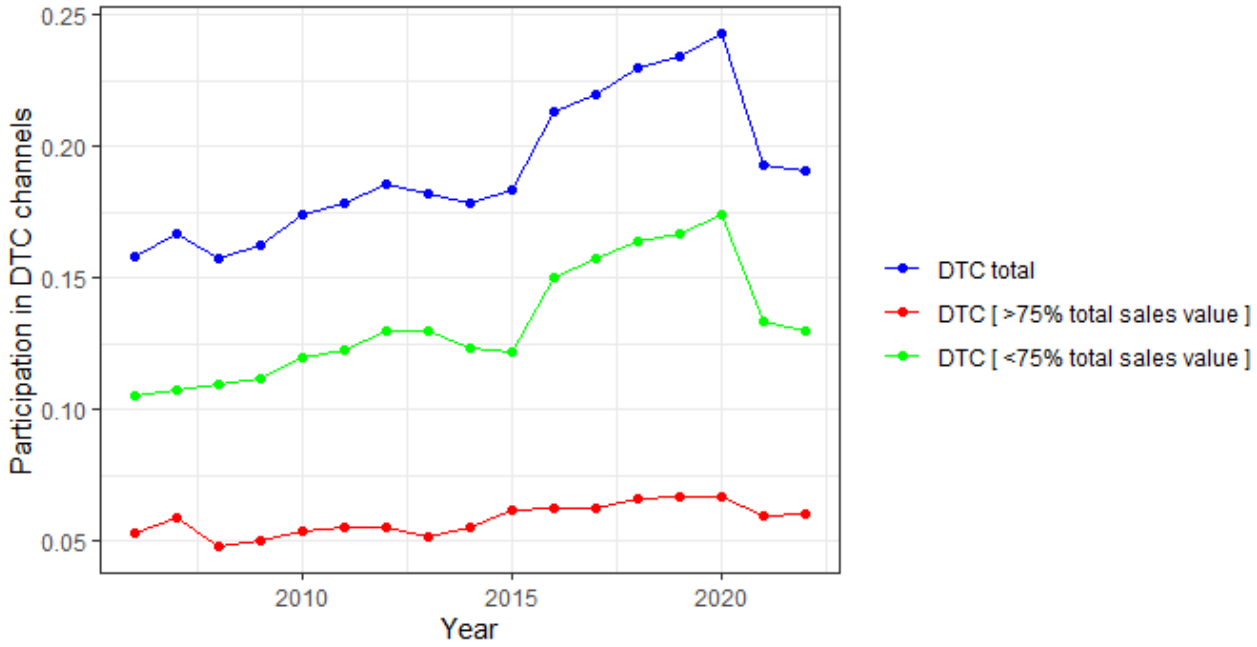

Figure 2.2. Evolution of DTC channels participation per year from 2006 to 2022, in percentage of farms using DTC channels. Source: French FADN 2006-2022

2.3 Data

2.3.1 Farm-Level Dynamics of DTC Channel Participation

We create an unbalanced panel using data from the FADN covering the period from 2006 to 2022[7]. Managed by the French Ministry of Agriculture, the FADN predominantly includes medium to large-sized farms[8], resulting in an average farm size larger than those reported in the AC. This database contains around 7,000 farms surveyed annually, with about 10% renewed every year. Although farms are typically observed for an average of about five consecutive years, some farms may be observed only once, while others might be observed intermittently for several years. Hence, the analysis can solely focus on marketing transitions, as farms joining or leaving the sample within a specific year could not be considered as entering or exiting the agricultural sector. To ensure accurate estimations, the sample is limited to farms that have been consistently present in the database for a minimum of four consecutive years. This criterion allows for observing farms over an adequate duration and calculating lagged explanatory variables. Our unbalanced dataset encompasses 11,050 farms, resulting in 91,141 one-year transitions observed during the period from 2006 to 2022. These transitions also involve farms staying in the same marketing channel, which happens most frequently.

In order to capture the farm direct marketing dynamics over time, the Markov transition probability matrix is computed to determine the likelihood of a farm change in DTC channel involvement - either increasing or decreasing - from one year to another. As explained previously, farmers are categorized into three marketing channel groups based on how much they sell directly. One group sells exclusively through long food supply chain (LFSC), while the two others include farmers who use direct sales channels to varying degrees. These groups distinguish between farmers

[7] While data on Direct Marketing in the French FADN has been accessible since 2006, information regarding the economic size of farms has only been available since 2010. Hence, we chose the 2010 to 2021 period for analysis.

[8] This refers to farms with a standard output equal to or exceeding €25,000.

whose direct sales represent less than 75% of their total sales value and those for whom direct sales make up more than 75% of their overall sales value.

Table 2.1 illustrates the results on the transition matrix. The main diagonal of the transition matrix displays the percentage of farms that have remained in the same level of involvement in DTC channel throughout the period of analysis. The majority, more than 96%, stay in their initial level of involvement in DTC channel regardless of which initial state is being considered. This strong persistence could be due to our examination of transitions within a one-year period, which might not provide enough time to detect substantial changes. However, farms engaged in DTC sales are more inclined to transition away from their initial state compared to those solely involved in LFSC. In particular, they show a relative high probability of reducing their involvement in DTC channels over a year. Farms with over 75% of direct sales show a 2.58% probability of shifting to LFSC over a year, whereas those with less than 75% of direct sales exhibit a 7.18% probability. In addition, farms with over 75% of direct sales have a 3.99% probability of shifting to less than 75% of direct sales.

Farmers can reduce their reliance on DTC channels in order to switch to DTR channels, implying that their level of commitment to the SFSC does not change. Since 2010, the French AC has provided data on DTR channels, including direct sales to retailers, large stores, restaurants, and institutions. By analyzing information from the 2010 and 2020 French AC, we can assess whether farmers seek to enhance their involvement with either DTR channels or LFSC, when decreasing their reliance on DTC channels. Based on this information, we identify four marketing channel strategies according to the presence or absence of an intermediary. Farmers have the option to engage in LFSC exclusively, participate in DTC channels, DTR channels, or utilize both DTC and DTR channels. It is worth noting that farmers engaged in the various above defined SFSC strategies may also sell their production through LFSC. The dataset spanning from 2010 to 2020 comprises 242,436 farms, resulting in 484,872 ten-year transitions observed over the specified period. Farms in this sample have maintained a continuous presence in the database throughout the ten consecutive years from 2010 to 2020.

Table 2.2 presents the transition probability matrix depicting change across various marketing strategies over ten-year from 2010 to 2020. The descriptive analysis provided here is solely for informational purposes. Our econometric analysis cannot include an examination of DTR channel transitions due to the absence of such information in the FADN database. Data show a substantial likelihood of farmers involved in SFSC transitioning exclusively to LFSC over a decade, with an even higher probability for those engaged in DTR channels rather than DTC channels. Farms involved in DTC channels exhibit a 37% likelihood of transitioning exclusively to LFSC over a ten-year period, compared to a 18.5% (15.54 + 2.95) probability of transitioning to DTR channels. In addition, farmers engaged in DTR channels have a 62.36% probability of transitioning exclusively to LFSC over a ten-year period, compared to a 17.82% (9.37 + 8.45) likelihood of transitioning to DTC channels. Furthermore, our findings indicate that farmers involved in both DTC and DTR channels show a lower likelihood to shift towards exclusively selling through LFSC compared to those involved in either DTC or DTR channels alone. Overall, our findings indicate that farms, when decreasing their reliance on DTC channels, primarily shift towards exclusively selling through LFSC rather than DTR channels.

Table 2.1. Observed one-year transition across different level of participation in DTC channels between 2006 and 2022

	LFSC	DTC [<75% sales value]	DTC [>75% sales value]	Total
LFSC	51 340	1006	78	52 424
	(97.93)	(1.92)	(0.15)	
DTC [<75% sales value]	765	9 683	211	10 659
	(7.18)	(90.84)	(1.98)	
DTC [>75% sales value]	113	175	4093	4381
	(2.58)	(3.99)	(93.43)	
Total	52 218	10 864	4382	Total = 67 464

Source: French FADN 2006-2022

Table 2.2. Observed ten-year transition across different marketing strategies between 2010 and 2020

	LFSC	DTC	DTR	DTC + DTR	Total
LFSC	179 874 (86.30)	14 580 (7.00)	4415 (1.99)	9830 (4.72)	208 429
DTC	8274 (37.84)	9550 (43.67)	645 (2.95)	3398 (15.54)	24 867
DTR	2636 (62.36)	396 (9.37)	838 (19.82)	357 (8.45)	4227
DTC + DTR	1748 (22.09)	2287 (28.90)	483 (6.10)	3395 (42.90)	7913
Total	192 532	26 813	6111	16 980	Total = 242 436

Source: French Agricultural Census 2010-2020

2.4 Explaining transition probabilities

In this study, we investigate how certain variables influence the dynamics of participation in DTC channel at the farm level while addressing endogeneity concerns. Transition probabilities are defined as a function of the profitability of the farming activity, farmland size, the average income around farm city and the COVID-19 crisis. Table 3 reports descriptive statistics for these variables. Table A2.1 in appendix exhibits a weak correlation between these variables, which mitigates the problem of multicollinearity. All explanatory variables are lagged by one year.

2.4.1 Farm profitability

The farm net income per non-salaried annual work unit (AWU) is used as a proxy for profitability in farming. The effect of DTC channel participation on farmer income remains unclear such that farmers may find it difficult to rely exclusively on DTC channels for their livelihood (Chiaverina et al., 2023). Engaging in DTC channels enables farmers to capture a greater portion of the consumers' expenditure on food by removing intermediaries from the supply chain. The intangible qualities associated with the reconnection between farmers and consumers allows farmers to command a price premium for their products. Finally, DTC channel enhances farmer income by avoiding the variability in farm-gate prices experienced in conventional markets (Detre et al., 2011; Govindasamy, Hossain, & Adelaja, 1999; King et al., 2014; Le Roux et al., 2010; Mundler & Jean-

Gagnon, 2020; Uematsu, 2011; Verhaegen & Van Huylenbroeck, 2001). However, their sales volume remains limited while facing higher production and commercialization costs, including significant expenses for labor, packaging, and transportation, as well as transaction costs such as those associated with acquiring information, negotiation, and control. They may even have to set prices that do not adequately cover their production costs due to intense competition with other DTC channels and a deep social commitment to their community resulting in self-exploitation (Galt et al., 2016, 2019).

Instead, economic pressures often drive farmers to opt for a hybrid approach, combining DTC channels and conventional supply chains (Ilbery & Maye, 2006; Ilbery et al., 2004; Ilbery & Maye, 2005a, 2005b). This diversification strategy helps farmers to minimize their marketing risks and improve their economic perspectives, notably by providing access to a larger and steadier customers base and facilitating the transfer of surplus products between different channels (Kim, Curtis, & Yeager, 2014; Le Roux et al., 2010; Park & Lohr, 2007; Uematsu, 2011). Some qualitative studies show that farms frequently transitioning in and out of diverse supply chains in order to address immediate economic imperatives (Ilbery & Maye, 2006; Ilbery et al., 2004; Ilbery & Maye, 2005a, 2005b). This suggests that as the net income of farmers highly engaged in DTC channels decreases (rises), there is an increased (decreased) likelihood of them diminishing their direct sales. Conversely, farmers solely involved in LFSC are more (less) likely to engage in DTC channels as their net income decreases (increases).

2.4.2 Farmland size

Farmland size is proxied by the agricultural utilized area (UAA) indicator. Farmers engaged in DTC channels can express a desire to expand their operations due to the imperative need for them to operate at a scale that guarantees a minimum income or sustain a livelihood solely through farming (Aggestam, Fleiß, & Posch, 2017; Berti & Mulligan, 2016; Fleiß & Aggestam, 2017). They may also seek expansion primarily to enhance the profitability of their business as larger DTC

channels farms typically demonstrate stronger economic performance (Bauman, Thilmany, & Jablonski, 2019; Park, 2015).

However, expanding their operations might imply reducing their direct sales due to various constraints hindering scalability in DTC channels. Participating in DTC channels involves significant time and labor demands, attributable to additional responsibilities encompassing processing, distribution and marketing, alongside labor-intensive production methods like organic or agro-ecological practices (Bruce & Castellano, 2017; Rucabado-Palomar & Cuéllar-Padilla, 2020). Ensuring a consistent supply of food items that encompass a reliable quantity and diverse varieties also poses challenges for farmers engaged in DTC channels, due to seasonal fluctuations, consumer preferences, and constraints in production capacity (Griffin & Frongillo, 2003; Kupke & Page, 2015; Oglethorpe & Heron, 2013; Plakias, Demko, & Katchova, 2020). Farmers are also constrained by the lack of processing, storage and distribution infrastructure or equipment outside the mainstream food supply chain (Aggestam, Fleiß, & Posch, 2017; Berti & Mulligan, 2016; Cleveland et al., 2014; Mount, 2012; Ross, 2006; Rucabado-Palomar & Cuéllar-Padilla, 2020). In addition, they face financial and capital constraints in starting up or expanding their business including difficulties in accessing credit or public aid (Cerrada-Serra et al., 2018; Ross, 2006).

Farmers engaged in DTC channels have also the opportunity to expand by engaging in food hub operations, which aggregate and distribute high-quality and differentiated food products from multiple small farms and supplying them to various outlets such as grocery stores, schools, hospitals, and restaurants (Berti & Mulligan, 2016; Cleveland et al., 2014). This scale-up approach via “aggregation” and “network” contrasts with the conventional method of achieving "economies of scale" through capital investments (e.g. lands) and vertical integration within centralized large-scale supply chains (Berti & Mulligan, 2016). It enables farmers to expand their operation while continuing to receive a value-added premium derived from the reconnection between producers and consumer, based on shared goals and values such as trust, authenticity, safety, and confidence (Mount, 2012; Mount & Smither, 2014). Hence, we expect to find a negative effect of farmland size on DTC channel participation. This indicates that as farmland size grows, farmers active in DTC

channels are more likely to reduce their direct sales. Conversely, farmers solely involved in LFSC are less likely to engage in DTC channels as farm size increases.

2.4.3 Average income around farm city

We utilize the average household income within a 20km radius of the farmers' city as the proxy of the demand for food products from DTC channels. We obtain municipal average household income data from the World Inequality Database and calculate, for each farmers' city, the average household income of municipalities within a 20km radius.

Urban consumers with higher education and income levels are the primary purchasers of food grown in DTC channels (Brown, Dury, & Holdsworth, 2009; Guthman, 2008; Hinrichs, 2000; Hinrichs & Allen, 2008; Tregear, 2011). Increased income would allow consumers to increase their spending on food products that are prominent in DTC channels (especially fruits and vegetables) (O'Hara & Low, 2016). In addition, DTC channels may be able to capture an increase in consumers' purchasing power by offering products that meet their desired quality attributes, such as from direct relationships with farmers based on trust, transparency and shared values, as well as the freshness and quality of food when produced locally (Brown, 2003; Brown, Dury, & Holdsworth, 2009). As a result, DTC channels are more likely to develop in more affluent areas, as they offer farmers better economic opportunities through access to more affluent customers. (Blumberg, 2018; Corsi, Novelli, & Pettenati, 2018; Govindasamy, Hossain, & Adelaja, 1999; Jarosz, 2008). On the other hand, a limited customer base requires farmers to combine multiple DTC channels or DTC channels with conventional supply chains to ensure a decent income (Bruce & Castellano, 2017; Fleury et al., 2016; Heiss et al., 2015; Rucabado-Palomar & Cuéllar-Padilla, 2020). The average household income around farmers' city, used as a proxy of the demand for food items from DTC channels, might positively influence farmers' participation in DTC channels. This suggests that as the average household income rises, farmers involved in DTC channels are more inclined to expand their direct sales, while those exclusively involved in LFSC are more likely to engage in DTC channels.

However, some studies have found no effect of standard of living on farmers' participation in direct sales (Blanck et al., 2011; Stephenson & Lev, 2004; Thilmany, Bond, & Bond, 2009; Wolf, Spittler, & Ahern, 2005; Zepeda & Li, 2006). The literature indicates that consumers are willing to pay a premium for attributes associated with a direct relationship with farmers, enabling farmers to command higher prices. However, prices in DTC channels have been observed to be comparable to those in conventional supply chains, indicating that DTC channels remains economically accessible for price-sensitive low-income consumers (McGuirt et al., 2011; Valpiani et al., 2015; Valpiani et al., 2016). Furthermore, consumers with higher incomes may have a greater opportunity cost associated with purchasing, preparing, and serving fresh, unprocessed food at home compared to processed products. This may result in a decreased inclination to purchase food through direct-to-consumer channels (Maples et al., 2013; O'Hara & Low, 2016). Lastly, an increased demand for food driven by higher incomes could result in higher competition levels between DTC channels in urban and high-income areas. This intensified competition might prompt farmers to move away from DTC channels. Similar results have been reported in the case of an increased demand for food caused by population growth. This surge leads to a rise in participants entering DTC channels only in scenarios with a small initial population, where there is greater availability of farmland and no market saturation (Bonanno, Berning, & Etemadnia, 2017; Connolly & Klaiber, 2019; Corsi, Novelli, & Pettenati, 2018).

2.4.4 Covid-19 crisis

The COVID-19 crisis, which mainly covers the period 2020 and 2021, might negatively influence farmers' dynamics in DTC channels. This suggests that during the COVID-19 crisis, farmers involved in DTC channels are more inclined to reduce their direct sales, while those exclusively involved in LFSC are less likely to engage in DTC channels. Several research studies have underscored the detrimental effects of the COVID-19 crisis on producers involved in DTC channels, despite their capacity for resilience (Thilmany et al., 2020, 2021). One explanation is the enforcement of social distancing measures, which resulted in the temporary closure of face-to-face

markets, like farmers' markets (Benedek et al., 2022; Chiffoleau et al., 2021; Richards & Rickard, 2020; Thilmany et al., 2021).

2.4.5 Control variables

Additionally, we control in our model for the farm specialization as it significantly affects the economic performance of farms involved in DTC channels, and might therefore indirectly have an influence on farm DTC channels dynamic. Farmers engaged in DTC channels have better economic performances when producing high-value crops (Bauman, Thilmany, & Jablonski, 2019; Detre et al., 2011; Uematsu, 2011). We use market gardening farms as the baseline farm specialization because high value crops (vegetables and fruits) are the most frequently represented types of production in SFSC (Bermond, Guillemin, & Maréchal, 2019; Detre et al., 2011).

Table 2. 3. Definition and descriptive statistics of explanatory variables

Variables	Definition	Unit	Source	Mean	Std.Dev.
Farm net income nsAWU	Farm Net income per non-salaried AWU	€	FADN	26790.52	66705.29
UAA	Utilised agricultural area	Hectare	FADN	97.65	83.90
Average household income - 20km	Average household income within a 20km radius of the farmers' city	€	World Inequality Database	16351.75	2531.86
COVID-19	The binary variable equals 1 if the year matches the timeframe of the COVID-19 crisis (2020 and 2021)	Dummy	FADN		
Farm specialization					
Livestock	Specialization in livestock	%	FADN	0.37	(0.48)
Arboriculture	Specialization in arboriculture	%	FADN	0.04	(0.20)
Field crops	Specialization in field crops	%	FADN	0.23	(0.42)
Viticulture	Specialization in viticulture	%	FADN	0.15	(0.36)
Mixed cropping and livestock	Specialization in mixed cropping and livestock	%	FADN	0.14	(0.35)

2.5 Method

2.5.1 Modelling the Dynamic of DTC channel engagement using a markov chain model accounting for endogeneity

2.5.1.1 Definition of different levels of participation in DTC channels

Farmers are sorted into three distinct marketing strategies according to the proportion of their sales dedicated to DTC channels. One group comprises farmers solely selling through LFSC, while the remaining two encompass farmers involved to different extents in DTC channels. We distinguish between farmers whose direct sales represent less than 75% of their total value sales and those for whom direct sales make up more than 75% of their total value sales.

2.5.1.2 Modelling Markovian process across DTC channel participation levels

Markov chain models (MCM) are widely used for modelling dynamic random phenomena in economics. For example, they have been employed in agricultural economics to examine farm structural change over time. To effectively analyze how farms transition across different levels of participation in DTC channels over time using MCM, we need to assume that such transition follows Markovian dynamics. The MCM asserts that the level of participation in DTC channel of a farm at a specific period is determined by a stochastic process that relies solely on its level of participation in DTC channel in the preceding period.

Let N represent the total count of farms within the population, and K denote the number of marketing strategies based on the level of participation in DTC channels. Herein, γ_{it} denotes the DTC channel participation decision made by a specific farm ($i \epsilon N$) at time ($1 \leq t \leq T$). The variable γ_{i1} is set to $j(\forall j = 0{,}1\ or\ 2)$ if farm i is categorized into marketing strategy j at time $t = 1$. Farms can enter or exit the farming sector during the observed period, thus leading to variations in the duration for which a farm is under observation. Consequently, we focus solely on farms that remain observable for at least four consecutive years within the 2006-2022 timeframe, forming a

sample comprising farms that persist in farming throughout this observed period. The trajectory of the marketing channel decisions for a specific farm i can be expressed as the vector $y_i = (y_{i1}, y_{i2}, \dots, y_{iTi})$.

Based on a first-order Markov process, we assume that the marketing decisions of farm i at any time $t(y_{it})$ depends only on its immediately preceding decision, that is, its marketing decision at time $t-1(y_{it-1})$. The sequence of observed random variables $(y_{i1}, y_{i2}, \dots, y_{iTi})$ are therefore not independent of each other. Consequently, we can derive the probability function describing the transitions of farms among various marketing strategies as:

$$f(y_i) = \prod_{t=1}^{T_i} P(y_{it}|y_{it-1}) \tag{2.1}$$

The expression $P(y_{it}|y_{it-1})$ is the transition probabilities, that is, the probability that farm i adopts a specific marketing strategy at time t given its marketing strategy at time $t-1$.

2.5.1.3 Accounting for heterogeneity

Suppose now that the observed sample of farms is divided into G homogeneous types instead of just one, each type grouping farms with a similar transition process. The density function of y_i, as a discrete mixing distribution with G support points, can be rewritten as (McLachlan & Peel, 2001):

$$f(y_i) = \sum_{g=1}^{G} \pi_g f_g(y_i) \tag{2.2}$$

Where $f_g(y_i)$ referred to as the mixed function, represents the probability function describing DTC channel dynamics in type g as defined in equation 2.2; and π_g denoted as the mixing distribution, indicates the proportions of farms that belong to each type g. It is noteworthy that these mixing proportions sum up to one.

A mixture of two types of farms ("almost stayers" and "likely movers") can be assumed in the population. Consequently, the density function of Y_i is conditional on the mixing distribution. This allows us to represent DTC channel dynamics as follows:

$$f(y_i) = \sum_{g=1}^{2} P(g_i = g) \left[\prod_{t=1}^{T_i} P(y_{it} = k | y_{it-1} = j, g_i = g \right] \tag{2.3}$$

Equation 2.3 reveals that under the M-MCM, DTC channel dynamics rely on two distinct sets of probabilities. The first term represents the probabilities associated with farm i belonging to a particular farm type g. Meanwhile, the subsequent term represents the probabilities related to transitioning across marketing categories, given that farm i belongs to type g.

2.5.1.4 Specification of the model

We use a non-parametric specification to estimate the likelihood of being classified into a specific type of farm DTC channel dynamics denoted as g. A discrete choice approach is employed to specify marketing transitions and postulate that an agricultural producers' decision to either maintain their current marketing strategy or switch to another one can be depicted through a random utility model.

The expected utility, denoted as U_{ijt}, is formally expressed as the benefit that farmer i may derive from engaging in marketing strategy j at time t. This utility is a function that incorporates not only farm profit but also various non-monetary advantages, such as personal interactions with consumers and the diversity of tasks associated with the marketing channel. We hypothesize that farmers opt for the marketing strategy that maximizes their overall utility. Hence, farmer i will transition from marketing strategy j to marketing strategy k at any time t if $U_{ikt} > U_{ijt}$ as illustrated in equation 2.4.

$$p_{ijkt} = P(y_{it} = k | y_{it-1} = j) = P(U_{ijkt} \equiv U_{ikt} - U_{ijt} > 0) \tag{2.4}$$

U_{ijkt} represents the net benefit derived from transitioning from marketing strategy j to k at time t for farm i. The probability of transitioning between distinct marketing strategies can be represented as a function that takes into account a set of explanatory variables. This is because the utility for the farmer is contingent upon the specific attributes inherent to both the farm and the farmer. Within the M-MCM, the transition probabilities will vary based on farm type whereas the effect of explanatory variables on these transition probabilities varies depending on the farm type. Given the multiple marketing strategies accessible to farmers, we use a multinomial logit model to estimate the likelihood of transitioning from marketing strategy j to k at time t as depicted in equation 2.5.

$$p_{ijkt} = P(y_{it} = k | y_{it-1} = j, g_i = g, X_{it-1}) = \frac{exp(\beta'_{jk|g} X_{it-1})}{\sum_{l=1}^{k} exp(\beta'_{jl|g} X_{it-1})} \quad (2.5)$$

Where $\beta_{jk|g}$ is a vector of parameters specific to each farm type $g = 1,2$ and jk transition and X_{it} are the explanatory variables considered. All the explanatory factors are lagged by one year because farmers typically base their decisions on changing their marketing strategy on information from the previous year. Using lagged explanatory variables helps minimize potential issues related to endogeneity, as it addresses the possibility that the marketing strategy could influence some of the explanatory variables employed in the model.

2.5.2 Estimation procedure

We use the maximum likelihood technique to estimate the parameters of the M-MCM. The log-likelihood (LL) function for the parameters (β) of the model can be expressed as:

$$LL(\beta) = \sum_{i=1}^{N} ln \left\{ \sum_{g=1}^{2} \pi_g \prod_{t=1}^{T_i} \prod_{j,k}^{K} [P(X_{it-1}; \beta_{jk|g})]^{d_{ijkt}} \right\} \quad (2.6)$$

Where $\beta_{jk|g}$ represents the vector of parameters to be estimated $\forall\, g = 1,2$ and $j, k = 1,2, \dots, k$; $P(X_{it-1}; \beta_{jk|g})$ is the conditional transition probability of transitioning from marketing

strategy j to k given farm i belongs to type g; d_{ijkt} is a binary variable; it equals one if farm i transitions from marketing strategy j to k at time t and zero otherwise.

The expected-maximization (EM) algorithm simplifies the optimization of the complex *LL* function into a set of easily solvable *LL* functions using a so-called "missing variable" (McLachlan & Krishnan, 2007; Saint-Cyr, 2022). This divides the initial log-likelihood into two components, represented by equations 2.7a and 2.7b:

$$LL_1 = \sum_{i=1}^{N} v_{i1} ln\pi_1 + v_{i2} ln\pi_2 \tag{2.7a}$$

$$LL_2 = \sum_{i=1}^{N}\sum_{g=1}^{2} v_{ig} \sum_{t=1}^{T_i}\sum_{j,k}^{K} d_{ijkt}\, ln\left[P(X_{it-1}; \beta_{jk|g})\right] \tag{2.7b}$$

The vector $v_i = (v_{i1}, v_{i2})$ represents a g-dimensional vector where $v_{ig} = 1$ if farm i belongs to type g and zero otherwise. Due to the unobservable nature of farm types, the variable v_i has to be estimated based on the observed marketing dynamic $y_i = (y_{i1}, y_{i2}, \dots, y_{iTi})$.

The iterative EM algorithm introduced by Dempster et al., (1977) comprises four distinct steps. The process begins by initializing parameter values randomly. This initialization is crucial for estimating the posterior membership probabilities v_{ig} by applying Bayes' Law. Subsequently, these probabilities serve as a basis to iteratively update the parameters across each iteration (p) as described in equation 2.8:

$$\beta^{(p)} = argmax_{\beta} \sum_{i=1}^{N}\sum_{g=1}^{2} v_{ig}^{(p)} \sum_{t=1}^{T_i}\sum_{j,k}^{K} d_{ijkt} ln[P\left(X_{it-1}; \beta_{jk|g}\right)] \tag{2.8}$$

The probabilities indicating whether a farm belongs to type g are then updated as follows:

$$\pi_g^{(p)} = \frac{\sum_{i=1}^{N} v_{ig}}{\sum_{i=1}^{N}\sum_{h}^{2} v_{ig}}, \forall g = 1,2$$

(2.9)

This procedure is iterated until convergence of the parameters and the observed log-likelihood value given by Equation 2.6.

2.5.3 Probability elasticities

Interpreting how the explanatory variables specifically affect the outcomes is challenging because the estimated coefficients represent marginal effects on log-odds ratios of transition probabilities. We opt to evaluate the influence of explanatory variables using elasticities that quantify the impact of a 1% shift in the *i*th explanatory variable on the transition probability as described in equation 2.10:

$$\delta_{jkt|g} = \left(\beta_{jk|g} - \sum_{l \neq k}^{K} \beta_{jl|g} p_{jlt|g}\right) X_{t-1}$$

(2.10)

$\delta_{jkt|g}$ represents a vector encompassing elasticities at the mean values of the explanatory variables within vector X_{t-1}; $\beta_{jl|g}$ is the vector containing estimated parameters; $p_{jlt|g}$ is the predicted probability of moving from marketing strategy j to k at time t conditional on belonging to type g.

2.6 Results

We start by estimating coefficients for all explanatory variables, and subsequently, we calculate the transition probability elasticities for each type of farm. The estimated coefficients indicate how much each explanatory variable contributes to the odds ratios. These ratios specifically capture the probability of a farm shifting away from a given marketing strategy, relative to the scenario of the farm staying within the same marketing strategy across consecutive years. Because

interpreting the values of the odds-ratio coefficients is challenging, the discussion will concentrate solely on the transition probability elasticities linked to the primary explanatory variables. We present findings solely for farms classified as “likely movers” to improve result comprehension, and given our primary interest in this subset. The average posterior probabilities of belonging to a specific type indicate that about 49.9% of the sample consists of farms, named the “likely stayers”, which tend to remain in their initial marketing strategy for at least the entire period of observation. Conversely, farms belonging to the second type, the “likely movers”, which are more likely to change their marketing strategy from one year to the next than the “likely stayers”, consist of about 50.1% of the sample. Table 2.4 reports the probability elasticities for farms of decreasing or increasing participation in DTC channels from one year to the next for farms categorized as “likely movers”.

We demonstrate a positive influence of farmland size (UAA) on the probability of transitioning from both under and over the 75% direct sales threshold participation to exclusive LFSC. More specifically, a 1% increase in farm size leads to a 0.36% (+/- 0.11%) increase in the probability of switching to exclusive participation in LFSC for farms that generate more than 75% of their sales from direct sales. For farms generating less than 75% of their sales from direct sales, the increase is 0.26% (+/- 0.07%). The size of the farmland has a negative influence on the probability of moving from exclusive participation in the LFSC to achieving less than 75% of sales through direct sales. In summary, our findings indicate that an expansion in farmland size raises the likelihood of transitioning away from DTC channels and reduces the likelihood of participating in DTC channels for farmers solely involved in LFSC.

An increase in farm net income leads to a decreased probability of reducing reliance on direct sales, either from more than 75% to less than 75% of total sales or from less than 75% of total sales to exclusively participating in LFSC. This suggests that farmers engaged in DTC channels can respond to profitability challenges by decreasing their direct sales. Furthermore, an increase in farm net income raises the probability of transitioning from marketing solely through LFSC to DTC

channels overall. This indicates that farmers who are exclusively involved in LFSC and make the transition to DTC channels are not doing so because of profitability challenges within LFSC.

We show that an increase in average income around the farm city increases the probability to transition from participating exclusively in LFSC to DTC channels overall. This may be due to the fact that a rise in average income around the farm city leads to a greater demand for local food, which in turn encourages farmers who sell exclusively through LFSC to make the transition to DTC channels. For farmers who make over 75% of their sales directly to consumers, an increase in average income around the farm city increases the likelihood of switching exclusively to LFSC. However, it reduces the likelihood of switching to less than 75% of their sales in direct sales. A rise in the average income around the farm city could result in increased competition and saturation in DTC markets. This, in turn, might motivate farmers highly engaged in DTC to choose a complete shift towards LFSC instead of persisting in direct sales with reduced levels of involvement. For farmers with less than 75% of their total sales coming from direct sales, an increase in average income around the farm city reduces the likelihood of transitioning exclusively to LFSC. However, it also decreases the probability of intensifying reliance on direct sales to more than 75% of total sales. Those findings might demonstrate the dual impact of a rise in demand for food products through DTC channels, which brings both opportunities and challenges, associated with saturation and further competition within these channels.

The COVID-19 crisis has a negative impact on participation dynamics in DTC channels. It reduces the likelihood of transitioning from exclusive LFSC sales to both more and less than 75% of direct sales, while increasing the probability of transitioning from both more and less than 75% of direct sales to an exclusive involvement in LFSC. In addition, the COVID-19 crisis makes it less likely for farmers to transition from direct sales of more than 75% to less than 75%, as they may prefer to abandon these channels altogether.

Table 2.4. Yearly probability elasticities for farms of decreasing or increasing participation in SFSC among 'likely movers'

	Decreasing DTC channel participation			Increasing DTC channel participation		
	DTC >75% toward DTC <75%	DTC >75% toward LFSC	DTC <75% toward LFSC	DTC <75% toward DTC >75%	LFSC toward DTC <75%	LFSC toward DTC >75%
UAA	.2138037*	.3585961***	.2621735**	-.3471727	-.9511236***	.3291194
	(.1098874)	(.1127972)	(.0791696)	(.22348)	(.1485703)	(.2336972)
Farm Net income nsAWU	-.1233481***	-.0191681	-.0306056**	.0113469	.0164847**	.0142102**
	(.0334537)	.0156852	(.0151207)	(.0113862)	(.0066672)	(.0069752)
Average household income - 20km	-1.046579**	1.368316***	-.7928019**	-1.253867**	1.142118***	3.565918***
	(.4789415)	(.5000371)	(.341685)	(.5225991)	(.3343228)	(.6951801)
COVID-19	-1.592675***	.3057504***	.2480919**	-.0484549	-.1528417***	-.3150472**
	(.0498655)	(.0242759)	(.0128953)	(.0333334)	(.0320638)	(.1258462)

Robust standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

2.7 Conclusion and discussion

2.7.1 Main results

In contrast to studies indicating a rise in participation in DTC channels, our research reveals a pattern of consistently low and stable engagement since 1970. Despite a recent surge between 2010 and 2020, participation in DTC channels experienced a decline during the COVID-19 crisis. From a transitional perspectives, DTC channels have experienced a prolonged pre-development phase for decades, before a recent take-off that was disrupted by the COVID-19 crisis (Geels, 2014; Rotmans, Kemp, & Asselt, 2001; Rotmans & Loorbach, 2009). This finding might suggest that DTC channels are far from surpassing their niche status and being able to meet food demand through local production.

In addition, we find that the predominant approach when engaging in DTC channels involves adopting a hybrid strategy that combines both DTC channels and longer supply chains. Theoretical research suggests that market participants often operate across multiple supply chains, indicating that their actions are not confined to a singular supply chain perspective (Benson-Rea, Brodie, & Sima, 2013; Kjellberg & Helgesson, 2006). As explained previously, a hybrid marketing approach helps farmers engaged in DTC channels to minimize their marketing risks by providing access to a larger and steadier customer base and facilitating the transfer of surplus products between different channels.

Moreover, our findings highlight that farmers involved in DTC channels are highly likely to reduce their reliance on direct sales over time. Farms that decrease their reliance on DTC channels predominantly redirect their focus towards increasing participation in LFSC rather than DTR channels. Those results underscore the dynamic nature of DTC channels, indicating their capacity to make supply chain adjustments in response to significant changes in the business environment (MacCarthy et al., 2016; Zinn & Goldsby, 2019). This is consistent with qualitative studies revealing that farms engaged in DTC channels frequently shift in and out of conventional supply chains due

to economic reasons (Ilbery & Maye, 2006; Brian Ilbery et al., 2004; Brian Ilbery & Maye, 2005a, 2005b).

Numerous economic factors are likely to hinder or facilitate the dynamics of participation in DTC channels. These include challenges related to farm expansion, economic profitability and demand, as well as short-term shocks such as the COVID-19 crisis. As farmland size increases, farmers involved in DTC channels are more likely to reduce their direct sales, regardless of their initial level of involvement. Additionally, this expansion reduces the likelihood of farmers exclusively involved in LFSC to engage in DTC channels. One possible explanation lies in the presence of various constraints that hinder the scalability in DTC channels. As their net income declines, farmers who are highly involved in DTC channels are more likely to reduce their direct sales in favor of a hybrid marketing approach that helps them to minimize their marketing risks. We also find that those with lower levels of participation in DTC channels are more likely to abandon them and participate exclusively in LFSC channels. Furthermore, farmers who are solely involved in LFSC are more likely to participate in DTC channels as their net income increases. This may indicate that profitability issues within the LFSC are not the sole reason for their decision to transition to direct sales. We find that the probability of shifting from participation in DTC channels to an exclusive involvement in LFSC increases during the COVID-19 crisis, which might be due to the temporary closure of face-to-face direct markets. Likewise, the COVID-19 pandemic decreases the probability of transitioning from solely participating in the LFSC to engaging in direct sales. We find an ambivalent effect of an increase in average income near the farm city. It encourage farmers solely engaged in LFSC to transition to DTC channels, while simultaneously prompting farmers highly involved in DTC channels to abandon them for LFSC instead of persisting in direct sales with reduced levels of involvement. For farmers who use a hybrid marketing strategy, it reduces the likelihood of transitioning exclusively to LFSC but also of relying on direct sales for more than 75% of total sales. The ambivalent results could stem from the fact that an increase in average income contributes to an increase demand for local food but also competition among farmers involved in DTC channels.

2.7.2 Limits

Despite implementing, a mixed Markov chain model and incorporating lagged explanatory variables to address endogeneity, our attempt to estimate the causal impact of economic factors on transition probabilities within DTC channels may still be influenced by this issue. While we cannot fully control for endogeneity issues, we can discuss how they may bias our results. Our study could face endogeneity issue from reverse causality, implying that the values of our explanatory variables may result from, rather than influence, our dependent variable (King, Keohane, & Verba, 1994). For instance, we find that higher average income near farm city might increases the probability that farmers solely engaged in LFSC to transition to DTC channels. However, average income can be mere consequence, rather than cause of participation in DTC channels. A higher participation in DTC channels in an area might increase income retention or attract high income population, favoring economic development and, thereby average income (Brown et al., 2014; Hughes et al., 2008; Hughes & Isengildina-Massa, 2015). The effect of average income on DTC channel involvement is therefore complicated by a positive reverse causal effect of DTC channel involvement on average income. Hence, the estimate of the effect of average income on DTC channel participation will suffer from upward bias. We could therefore reasonably infer that the true relationship is probably lower than it seems from our analysis.

Information on the direct-to-total sales ratio reported by farmers may suffer from measurement error. Measurement error represents the disparity between self-reported and objectively measured values. This discrepancy can stem from misreporting, where respondents intentionally or unintentionally provide inaccurate information, or misperception, involving inaccurate beliefs, particularly if the true value is beyond the respondents' control or knowledge capacity (Abay et al., 2023; Abay, Bevis, & Barrett, 2021). Misreporting can stem from respondents rounding their direct sales share, causing farmers to deliberately under-report or over-report it. This could also be attributed to status-related motives, leading to intentional over-reporting, or taxation concerns, prompting deliberate under-reporting. Under-reporting direct sales may be prevalent, as these direct transactions often contribute to the informal or underground economy (Timmons &

Wang, 2010). Misperception could be attributed to farmers' imperfect knowledge about the share of their sales from DTC channels. They might rely on predictions rather than concrete knowledge, contributing to measurement error. Measurement error in the dependent variable can cause bias and inconsistency when it is systematic and not random. Consider, for example, the simple possible case in which we underestimate the proportion of total sales derived from DTC channels of every survey farmers. If our focus is on estimating the causal impact of a decline in farm profitability on the proportion of total sales from DTC channels, the measurement error will not influence our causal inference. However, in the scenario where there is a systematic error within a subset of the sample—specifically, where farmers with income drops tend to under-report their direct sales to evade taxation, while our control group of farmers with a stable/increasing income is more likely to provide accurate reports of their direct sales—our causal inference regarding the impact of farm profitability on participation in DTC channels would be biased. The FADN database provides an ordinal categorization to gauge the extent of farmers' engagement in DTC channels, distinguishing farmers based on whether their direct sales constitute less than 75%, more than 75%, or none at all of their total sales. In certain studies, the extent of farmers' engagement in DTC channels is measured using a continuous variable, namely the proportion of direct sales in relation to their total sales (Azima & Mundler, 2022, 2023). Yet, the precision afforded by continuous measurement comes with the trade-off of increased vulnerability to measurement errors.

The generalizability of the results is limited because the way in which the data was used means that it is not representative of the general population. Our sample is limited to farms that have been consistently present in the database for a minimum of four consecutive years. Our analysis exclusively focus on marketing transitions, as farms joining or leaving the sample within a specific year could not be considered as entering or exiting the agricultural sector. Analyzing the decision of farmers who engage in DTC channels to leave farming would have been insightful, particularly in exploring the prevalence of this trend and the factors influencing it.

2.7.3 Policy implications and research perspectives

This study emphasizes the importance of moving beyond a simplistic view of farmers' involvement in DTC channels, which is mostly perceived as a form of protest against the conventional system. In contrast, we show that the most prevalent approach among farmers' participating in DTC channels involves adopting a hybrid strategy that combines these channels with conventional supply chains. We also demonstrate that the combination farmers' choose between DTC channels and conventional supply chains fluctuates significantly over time due to notably economic reasons. Taking into account the hybrid and dynamic involvement of farmers in DTC channels is therefore crucial, especially when assessing their impact on sustainability and designing policies to support them.

The majority of studies overlook the complex nature of DTC channels and instead rely on a simplistic binary variable to designate farms engaged in DTC channels when assessing their causal impact on sustainable factors. Neglecting the heterogeneity of DTC channels can be problematic, as the sustainability impact of DTC channels involvement can vary based on the degree of participation and types of channels used. For instance, Kim et al., (2014) demonstrate that marketing solely through farmers' markets provides farmers higher profitability than in conventional markets, but that the hybrid marketing approach helps them to minimize their marketing risks. In addition, some studies indicate that the forms of direct sales with the poorest economic performance are farmers' markets and community-supported agriculture, while other studies show the opposite (Jablonski, Sullins, & Thilmany McFadden, 2019; LeRoux et al., 2010; Uematsu, 2011). For a better understanding of the impact of DTC channels, it is necessary to consider their diversity by obtaining or utilizing comprehensive and longitudinal data regarding farmers' participation in these channels.

The policy objective should not be the pursuit of a transition to shorter supply chains as an end in itself, but rather as a strategic approach to enhance the sustainability of the existing food system. Despite the fact that DTC channels have no proven intrinsically beneficial outcomes and that their legal definition does not relate to sustainable requirements, the elimination of

intermediaries could contribute to improving the sustainability of the current food system through various causal mechanisms. These mechanisms vary depending on the outcome considered. For instance, SFSC participation might increase farmers' income by allowing farmers to capture a greater portion of the consumers' expenditure on food and obtaining a price premium (Chiaverina et al., 2023). SFSC might positively influence rural development by increasing income retention in the local economy (Hughes et al., 2008; Hughes & Isengildina-Massa, 2015) and reduces synthetic pesticide use thanks to less standardized marketing requirements (Chiaverina, Drogué, & Jacquet, 2024).

Several legal instruments and financial measures have been implemented to promote the development of DTC channels at local, national and European levels (Wallet & Dantas Machado Bouroullec, 2021). Financial measures from the 2014–2020 EU rural development policy supports investments in facilities for selling and processing agricultural products, setting up of producer groups and organizations and training and advisory services. The EU legislation implements some rule exceptions concerning safety trade conditions for direct sales and introduces labelling systems indicating the local origins of products in order to give producers an economic advantages. The high probability of farmers to decrease their involvement in direct sales or even completely abandon them over time question the relevance of such programs seeking to promote the development of DTC channels. They may be beneficial for farmers with a realistic chance of remaining in DTC channels but counterproductive for those who do not. The allocation of financial aid to farmers for the purpose of establishing or expanding their involvement in direct sales should account of their intended level and duration of participation in these channels. Policy support should be increased for farmers who heavily depend on direct sales, especially during the initial years following their transition to this sales method. However, it should not only be aimed at encouraging farmers to move into direct sales, but also at helping farmers to stay in this business.

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2.9 Appendix

Table A2.1. Correlation table

	UAA	Farm Net income nsAWU	Average household income - 20km	COVID
UAA	1.00			
Farm Net income nsAWU	0.0407	1.00		
Average household income - 20km	-0.0905	0.1085	1.00	
COVID	0.0018	0.0263	0.1249	1.00

Chapter 3

Does short food supply chain participation improve farm economic performance? A meta-analysis

This work is joint with Sophie Drogué, Florence Jacquet, Larry Lev and Robert King

Abstract

Many researchers, policy makers and food activists view Short Food Supply Chains (SFSC) as attractive lever for improving farm income and the sustainability of farming systems. However, the empirical evidence documenting the association between SFSC participation and farm economic performance has been mixed. In this study, through a meta-analysis using a logistic regression, we identify key factors to explain differences between studies that find better economic performance in SFSC and those that do not. Our meta-analysis consists of 48 studies published in English and French from 2000 to 2022 that examine the economic performance of farms engaged in SFSC. Based on far more empirical evidence than previous reviews, we find that the relationship between SFSC participation and farmer income remains ambiguous. More specifically the findings indicate that the reported effect of SFSC on a farm economic performance varies depending on location and the indicator used to capture the economic performance of farms. Studies conducted in Europe are more likely to report higher farmer income as are studies that use profit satisfaction metrics rather than measures of gross or net income. We also emphasize the need to interpret the reported results cautiously because few are based on causal inference methods. Furthermore, the very few studies that account for selection bias often do so with inadequate corrections.

Résumé

De nombreux chercheurs, décideurs politiques et militants considèrent les circuits courts (CC) comme des leviers attrayants pour améliorer les revenus agricoles et la durabilité des systèmes agricoles. Cependant, les preuves empiriques documentant l'association entre la participation aux CC et les performances économiques des exploitations agricoles sont mitigées. Dans cette étude, nous identifions, par le biais d'une méta-analyse utilisant une régression logistique, les facteurs clés permettant d'expliquer les différences entre les études qui constatent de meilleures performances économiques dans les CC et celles qui n'en constatent pas. Notre méta-analyse porte sur 48 études publiées en anglais et en français entre 2000 et 2022, qui examinent les performances économiques des exploitations agricoles engagées dans les CC. En nous basant sur des preuves empiriques beaucoup plus nombreuses que les analyses précédentes, nous constatons que la relation entre la participation en CC et le revenu de l'agriculteur reste ambiguë. Plus précisément, les résultats indiquent que l'effet déclaré de la participation en CC sur les performances économiques d'une exploitation agricole varie en fonction du lieu et de l'indicateur utilisé pour mesurer les performances économiques des exploitations agricoles. Les études menées en Europe sont plus susceptibles de faire état d'un revenu agricole plus élevé que celles menées en Amérique du Nord, tout comme les études qui utilisent des mesures de satisfaction des performances économiques plutôt que des mesures de revenu brut ou net. Nous insistons également sur la nécessité d'interpréter les résultats rapportés dans la littérature avec prudence, car peu d'entre eux sont basés sur des méthodes d'inférence causale. En outre, les très rares études qui tiennent compte du biais d’endogénéité le font souvent avec des corrections inadéquates.

3.1 Introduction

Local food supply systems (LFS) and short food supply chains (SFSC) have garnered increasing interest from academia and policy-makers in recent decades. Their development has been encouraged in the European Union (EU) by the European Agricultural Fund for Rural Development (EAFRD) devoting up to 10% of its expenditures to the promotion of food chain organization (Dwyer et al., 2016). Similarly, the U.S. Department of Agriculture through the 2014 Farm Bill invested $501.5 million over 5 years in diverse programs promoting local food production (Martinez, 2016). A growing number of farmers have chosen to market through SFSC and LFS even though this growth appears to be plateauing in the US (Low et al., 2015). By 2015, 15% of EU farms sold more than half of their production directly to consumers (European Parliament, 2016). In 2015, fewer than 9% of U.S. farms marketed food locally with 34% of them using only direct marketing channels (Martinez & Park, 2021).

There is no "official" definition of LFS, which has a strong subjective aspect related to local context. It refers most of the time to a distance of about 10 to 30 miles up to 100 miles between the point of production and the point of sale (Feldmann & Hamm, 2015) but can also be understood in relation to a recognized geographical area such as a county or a national park. By contrast, the EU rural development policy 2014-2020 has adopted a common definition of SFSC, defined as a supply chain including a minimal number of intermediaries (European Parliament, 2013). This is the case in France, where SFSC have been officially defined by the French Ministry of Agriculture as a marketing mode involving no more than one intermediary between the producer to the consumer and therefore including both direct sales as well as sales through an intermediary such as a cooperative or supermarket (LOI N° 2010-788, 2010; LOI N° 2010-874, 2010)[9].

[9] The term "circuit court" – short circuit - appears in the legal provisions, in Articles L. 1 and L. 111-2-2 of the Rural Code, in the 2010 law on the National Commitment for the Environment, and in the 2010 law on modernization of agriculture and fishing.

The dividing line and relationship between LFS and SFSC is blurred because SFSC embrace diverse forms overlapping most of the time the local concept, regrouped in the "sales in proximity" category (Aubry & Chiffoleau, 2009). Therefore, the European literature refers mainly to SFSC owing to the difficulties of defining the "local" concept. However, the North American literature refers to LFS covering both direct-to-consumer (DTC) and intermediated sales (e.g., sales to institutions or regional distributors). In addition, most studies included in this analysis do not look at SFSC or LFS in their entirety but rather at something more restrictive such as direct marketing (DM) or at some component of DM such as community supported agriculture (CSA) or farmer markets (FM).

Public opinion often considers agricultural incomes as structurally lagging behind incomes in other sectors (Katchova, 2008; Rocchi, Marino, & Severini, 2021). The modernization of agriculture has put pressure on farmers to invest continuously in new technologies and produce for mass food markets, thereby squeezing economic margins (Ploeg et al., 2000). This increasing pressure on the value captured by farmers in conventional supply chains has favored the emergence of local distribution channels (Marsden, Banks, & Bristow, 2000; Renting, Marsden, & Banks, 2003). They represent an opportunity for farmers to capture more of the overall margin by eliminating intermediaries and offer direct access to consumers who are more willing to pay for locally produced foods. They can, therefore, contribute to improving the viability of farm households and, indirectly, increasing the resilience of agricultural and food systems (Darnhofer, 2014; Finger & El Benni, 2021). However, the positive impact of SFSC on farm viability has been questioned because of numerous obstacles hindering their performance (Plakias, Demko, & Katchova, 2020; Rucabado-Palomar & Cuéllar-Padilla, 2020). SFSC have limited sales volume, and sellers receive prices that may not cover their higher production and marketing costs (e.g. significant labor, packaging and transportation expenses) as well as transaction costs (e.g. information, negotiation and control costs) (Cesaro et al., 2020; Kneafsey et al., 2013; Uematsu & Mishra, 2016).

To the best of our knowledge, one report and two articles have conducted systematic reviews of the effect of SFSC participation on farm economic performance in addition to other aspects of

their sustainability, and they find conflicting evidence (Chiffoleau & Dourian, 2020; Enthoven & Van den Broeck, 2021; Kneafsey et al., 2013). The results of the economic performance assessments of farms engaged in SFSC are difficult to compare because they are based on different methodologies and data. In addition, SFSC is an umbrella term covering a wide variety of marketing forms and levels of involvement such that the SFSC marketing strategies adopted by farmers influence their economic performance (Enthoven & Van den Broeck, 2021). Other variables such as farmer characteristics, time scale and geographic context might also affect the economic performance achieved within SFSC (Enthoven & Van den Broeck, 2021).

We conduct this meta-analysis to identify the structural characteristics that might explain differences between studies that find better economic performance in SFSC and those that do not. In addition, the literature search conducted for this meta-analysis is the first exclusively concentrated on the effect of SFSC participation on farm economic performance, allowing a more thorough analysis than previous reviews.

The paper is structured as follows. Section 3.2 and 3.3 provides a description of the methods employed in the meta-analysis and the systematic review protocol used. Section 3.4 presents the results of the meta-analysis. In the last two sections, we discuss our findings and present implications for future research and policy.

3.2 Methods

"Meta-analysis provides an objective approach to review empirical literature through applied statistical methods that allow testing for the effect of different factors on the empirical results reported in the literature" (Stanley & Jarrell, 2005). This meta-analysis seeks to identify the structural variables associated with conflicting results regarding the economic performance of farms involved in SFSC. First, we conduct a literature search to identify studies that examine the relationship between SFSC participation and farm economic performance (see part 2.1). Second, we identify structural variables that might distinguish studies finding positive economic effects for SFSC from those that do not (see part 2.2). Third, we use a logistic regression analysis that controls

for differences in study design characteristics to determine which factors can explain variations in the economic performance of farmers using SFSC (see section 3).

3.2.1 Literature search and selection criteria

The literature review identifies all the articles investigating the effect of SFSC participation on farm economic performance. It is performed by following the checklist of the Preferred Reporting Items for Systematic Reviews and Meta-analyses (PRISMA) (Liberati et al., 2009) (Figure 3.1). The review protocol containing information on the search terms, databases, eligibility criteria and selection process is presented below.

3.2.2 Information sources and literature search

The literature review was conducted using Scopus and Web of Science databases that are among the most valued databases for this field of interest. We applied a combination of three lists of comprehensive search terms detailed in Table A3.1, which explored the article title, abstract and keywords of every published document identified. The list including “Farmer”, ”Grower”, ”Rancher” or “Producer” keywords was mainly used in order to avoid an excess of unsuitable articles. Additional filters were used in order to limit the search within the social science discipline. The last search was run on October 16th 2022.

3.2.3 Eligibility criteria

The Population, Intervention, Comparison, Outcomes, and Study (PICOS) design criteria was used to identify both qualitative and quantitative papers (Table A3.2). All English or French articles published in peer-reviewed journals from January 2000 to October 2022 analysing the effect of SFSC participation on farm economic performance are included. Studies not conducted in Europe, Northern America or Australia where the specific context could induce different outcomes were also excluded. Finally, literature reviews, theses and dissertations, letters, book chapters, reports, author comments, and other grey literature were not included. Contrary to research articles

which are mainly written in English, grey literature is usually published in the language of the country where the studies take place. Consequently, grey literature we might consider would have not been representative of other non-English and French-speaking countries. In addition, studies from the grey literature have not necessarily been subject to a peer-reviewed process and it is thus more difficult to assess their quality.

3.2.4 Study selection process

Figure 3.1 describes the process by which articles were selected for this analysis. After removing duplicates between the Scopus and Web of Science databases, 1321 candidate records were identified. Then two independent reviewers screened article titles and abstracts using an Excel spreadsheet, and disagreements between them were resolved through discussion. During this phase, 1226 records not meeting the eligibility criteria were excluded. The eligibility assessment continued with the lead author reviewing in detail the full-text of the 95 remaining articles. Among those, 50 records fell outside the scope of the review (not farmer specific or not conducted in Europe, Northern America or Australia) and were removed. Finally, we added three relevant studies to the 45 articles identified previously, leading to a total of 48 articles included in the literature review[10] (Figure 3.1).

[10] One relevant study was not identified through the PRISMA selection process because it was slightly outside the period range of this meta-analysis (LeRoux, Schmit, Roth, & Streeter, 2010), another was published in a journal not included in Web of Science or Scopus(Richard, Chevallier, Dellier, & Lagarde, 2014) while the third one was not identified for unknown reasons (Park, 2015).

3.2.5 Data Collection Process

Content analysis was conducted by lead author while a second author checked the extracted content. Every selected article was carefully read and the following information was tabulated by the lead author: authors, year, setting, supply chain characteristics, methodology, sampling, outcome unit, outcome focus and the effect found (Table A3.3 and Table A3.4).

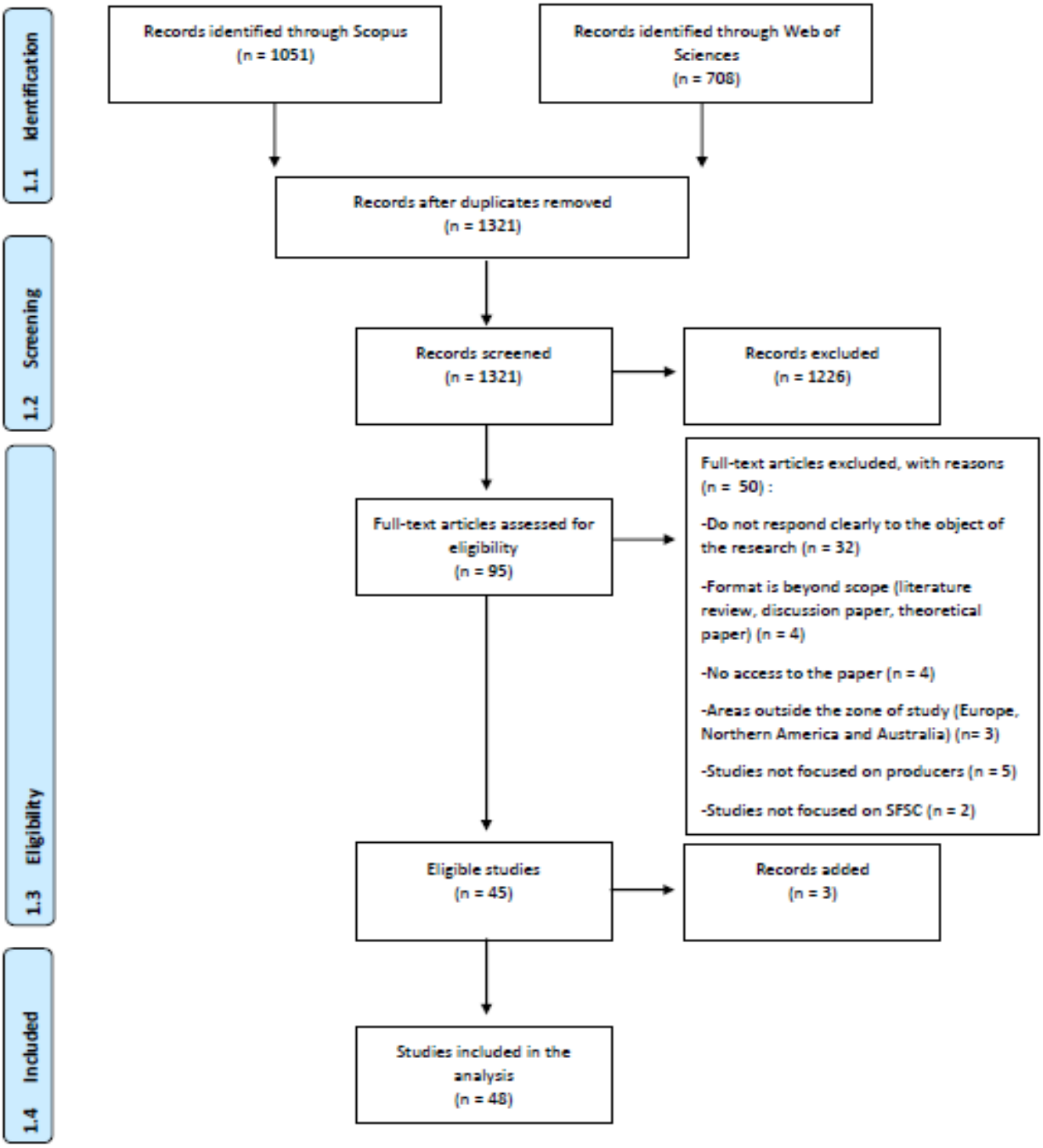

Figure 3.1. The PRISMA flow diagram

3.3 Meta-analysis

3.3.1 Structural variables

There is no guidance on which explanatory variables we should use; however, there are some study design characteristics that the literature indicates that may have an impact on the economic performance of farmers in SFSC. In addition, some structural variables that have been frequently investigated in other meta-analyses might also affect the economic performance of farmers in SFSC. In this study, we classify the structural variables investigated into five categories: data sources (secondary or survey data), study characteristics (study period, location, duration and number of SFSC forms examined), data analyses (endogeneity correction and analysis method) and dependent variables (outcome unit). Table 3.1 presents these variables, which are identified and coded.

First, we include variables that account for the nature of the data used in different studies. Because study accuracy depends upon the quality of the data analysed, data should be accurate and contain few and only minor errors. Consequently, the data source is critical for the analysis. Data from secondary sources usually have larger farm samples, increasing the generalizability of the study results. In addition, their larger sample sizes provide results with lower standard errors, making it easier to distinguish the effects of SFSC from random noise (Lee, Choe, & Park, 2015). However, they lack detail and flexibility due to the use of predetermined categories (Lee et al., 2015). Kneafsey et al. (2013) argue that the positive results found by localized case studies, which often use small sample questionnaires, contrast with findings from large surveys, which more often report lower economic performance. The number of respondents from studies identified varies greatly, ranging from 3 to 78,559 (Table A3.4). Twelve percent of the studies rely on samples that reflect the entire farm population (e.g. studies with samples based on census or representative sample data). We control for two types of data sources used in studies identified: field surveys and secondary databases.

Most of the studies use data for one year which may not be sufficient to provide a clear view of the economic performance of farmers engaged in SFSC. Farmers entering in SFSC may need

several years before becoming viable, as SFSC participation may require investments and developing a customer base (Clark, 2020; Dono, Buttinelli, & Cortignani, 2022). Studies based on short-term data collection might, therefore, produce results more favorable to SFSC because they do not account for this establishment period. In addition, once a firm is established, time-varying factors (economic, climatic, etc.) can cause economic performance to vary over time. Therefore, panel data can help us to understand whether the positive performance is just a one-time occurrence or something the firm achieves consistently. To test the effect of using multiple year datasets, we include a duration variable composed of two categories: one year and multi-year.

The motivation for distinguishing between different study periods is that we want to examine whether the returns to SFSC participation have been stable, increasing or declining over time. In addition, compared to earlier studies, later studies generally display improvements in the models, methods and data employed. For example, all of the limited number of research studies that evaluate the causal impact of SFSC on farm economic performance with endogeneity correction were conducted since 2010. Similarly, in Europe, questions on supply chain participation are more detailed in the recent farm accountancy data network (FADN) surveys and agricultural census than the previous ones, allowing for studies with more representative and larger samples.

We also test whether results differ by location. Farming systems vary across countries and continents, which might affect the economic performance found in SFSC. In addition, farmers involved in SFSC might have different motivations and face different challenges depending on their location. To test for the role of location, we have classified the samples into two regions: Northern America and Europe.

Many studies fail to distinguish among SFSC types, even though there are a wide diversity of SFSC forms (Aubry & Kebir, 2013). For example, studies estimating causal impact often use a binary variable to designate farms using SFSC and provide limited or no descriptive statistics on the forms of SFSC used by farms in their samples. Considering all SFSC to be the same might blur the effect of SFSC on economic performance because it combines what could be opposing results of different SFSC types. In this meta-analysis, it is difficult to consider the different SFSC forms given

the limited information available. However, we can distinguish between studies investigating the economic performance of a specific type of SFSC and those involving multiple SFSC forms. We test whether the results from studies focused on a single form of SFSC (FM and CSA in our case) differ from those that look at SFSC all inclusively.

Although a few studies evaluate the effect of SFSC on farm incomes based on causal inference methods, only a subset of these studies make use of regression analysis methods accounting for selection bias. This is partly due to the difficulties of measuring quantitatively the economic benefits of SFSC that could be invisible and confidential (Kneafsey et al., 2013) while finding valid instrumental variables (IVs) (which are often used to address endogeneity issues) is one of the most challenging tasks in applied agricultural economic analysis (Kubitza & Krishna, 2020). We test the effect of employing causal inference accounting for selection bias by including a dummy variable equal to 1 if studies use such methods. Those studies might provide different results because they control for unobserved factors affecting the adoption of SFSC that are correlated with farm income. When selectivity corrections are neglected, results might be biased indicating that earnings are over or underestimated.

Some studies examine the economic implications of SFSC involvement for farm viability while others compare the economic performance of farmers in SFSC to those in LFSC (long food supply chains). Consequently, they might provide different conclusions: farmers in SFSC might (not) be economically viable but achieve lower (higher) economic performance than ones in conventional markets. To test whether the nature of the analysis (relative/absolute) influences the results, we define a binary variable that distinguishes studies looking at viability of farms in SFSC from those comparing economic performance between SFSC and LFSC.

To investigate whether the economic effects of SFSC involvement might be affected by the types of economic measures used, we group the numerous economic indicators into three main categories: gross income, net income and farmer self-assessment of their business situation. First, studies considering gross income might provide more positive results than ones using net income because they do not consider production costs that could be higher in SFSC due to their high labor

requirements. Second, we must recognize that the use of subjective performance measures may lead to findings that differ from those based on objective performance measures. In many studies, subjective and objective measures of farm performance have been often treated as equivalent although they are often not correlated (Jackson-Smith, Trechter, & Splett, 2004; Mäkinen, Rantamäki-Lahtinen, Ylätalo, & Vehkamäki, 2009). One explanation is that farmers are not very familiar with economic indicators typically used in business analysis. They rate their own financial success based on the liquidity available in their bank account for private consumption and to pay the bills (Mäkinen et al., 2009). Subjective ratings therefore reflect a broader view of farm performance than objective measures focused on more specific financial indicators capturing the production side of agriculture at the enterprise level. Subjective measures most often focus on overall performance at the household level reflecting the consumption possibilities of the farm family depending on both farm and nonfarm incomes. SFSC farmers are more likely to rely on non-agricultural diversification activities (e.g. equestrian activities) (Park, Paudel, & Sene, 2018; Rocchi, Randelli, Corsini, & Giampaolo, 2019) and off-farm work (Bruce & Som Castellano, 2016) helping them to stabilize their total household income (Mishra et al., 2002). In addition, these studies are more likely to rely on different types of methods (e.g. logistic regressions) and data (field survey) than other ones.

3.3.2 Regression model

This meta-analysis examines the impact of the previously described structural variables on the reported economic performance of farms engaged in SFSC. A logit regression is used to model the likelihood of a study finding a positive effect of SFSC on farmer economic performance as a function of the structural variables (Maddala, 1986). The model assumes an underlying latent success variable y_i^* defined by the relationship:

$$y_i^* = \beta' x_{ik} + \mu_i \tag{3.1}$$

Where we assume that μ_i are IN$(0, \sigma^2)$. However, in practice we observe y defined by:

$$y_i = 1, \qquad if \;\; y_i^* > 0, \qquad y = 0 \; otherwise \tag{3.2}$$

According to the logit model, the probability of a study finding a positive effect of SFSC on farmer economic performance ($Y_i = 1$), given its characteristics (x_i) is $Prob[Y_i = 1 \mid x_i]$ and can be specified as:

$$Prob[Y_i = 1 \mid x_i] = \frac{exp(x_i'\beta + \varepsilon_i)}{\{1 + exp(x_i'\beta + \varepsilon_i)\}} \tag{3.3}$$

The probability of finding a negative/neutral effect, $Prob[Y_i = 0 \mid x_i]$, is therefore

$$\begin{aligned} Prob[Y_i = 0 \mid x_i] &= 1 - Prob[Y_i = 1 \mid x_i] \\ &= 1 - \left[\frac{exp(x_i'\beta + \varepsilon_i)}{\{1 + exp(x_i'\beta + \varepsilon_i)\}}\right] \\ &= \frac{1}{1 + exp(x_i'\beta + \varepsilon_i)} \end{aligned} \tag{3.4}$$

The relative odds of finding a positive versus negative effect are given by

$$\begin{aligned} \frac{Prob[Y_i = 1 \mid x_i]}{Prob[Y_i = 0 \mid x_i]} &= \frac{[exp(x_i'\beta + \varepsilon_i)][1 + exp(x_i'\beta + \varepsilon_i)]}{[1 + exp(x_i'\beta + \varepsilon_i)]} \\ &= exp(x_i'\beta + \varepsilon_i) \end{aligned} \tag{3.5}$$

By taking the logarithms of both sides,

$$ln\left[\frac{Prob[Y_i = 1 \mid x_i]}{Prob[Y_i = 0 \mid x_i]}\right] = x_i'\beta + \varepsilon_i \tag{3.6}$$

The maximum likelihood approach can be used to estimate the above equation.

The reduced form of the model is

$$\begin{aligned} EEFFECT = \; & \alpha_0 + \beta_1 DSOURCE + \beta_2 DURATION + \beta_3 PERIOD \\ & + \beta_4 LOCATION + \beta_5 NSFSC + \beta_6 DANALYSIS \\ & + \beta_7 NANALYSIS + \beta_8 MEASURE \end{aligned} \tag{3.7}$$

where our binary dependent variable (EEFFECT) equals one for studies reporting a positive effect of SFSC on farm economic performance and 0 for studies reporting a neutral or negative effect. The selected explanatory variables for this study include the data source (DSOURCE), the duration of data (DURATION), the period when the studies were set up (PERIOD); the location where the studies are conducted (LOCATION); the number of SFSC forms considered ($NSFSC$); whether the analysis employs causal inference accounting for selection bias (DANALYSIS); whether comparisons with performance in LFSC are made (NANALYSIS) and the types of economic measures used (MEASURE). A complete description of the variables that have been employed is given in (Table 3.1).

3.4 Results

3.4.1 Descriptive Statistics

Table 3.1 presents the frequency distribution for each of the structural variables examined. Approximately 54% of the 48 studies included in this analysis report a positive impact of SFSC participation on farm economic performance while 46% exhibit no effect or a negative impact. The number of publications evaluating the economic performance of farmers in SFSC has dramatically increased since 2016, reflecting increased research interest in this topic. More than 54% of the publications in this analysis were completed between 2016 and 2022. Most of the studies were conducted in North America (70%), particularly in the US[11]. The larger number of US articles may be explained by the availability of data, publication bias (number of academics in the US, etc.) and because the review is looking only at English and French language literature.

Among the 48 studies considered, 32 examine whether farmers using SFSC are more viable or have better economic performance than they would in conventional supply chains while the

[11] Although only studies conducted in developed countries were considered in this analysis, a single one was identified in Australia so that it was included in Europe.

remaining 16 studies consider whether farmers participating in SFSC are viable. The studies focus on one of three alternative performance measures; net income (60%), gross income (17%), or a self-assessment of the business situation (23%). Most studies rely on field surveys (60%) with data for a single year (85%). Only a few studies make use of regression analysis methods accounting for selection bias (13%). A limited number of studies focus on one SFSC form (25%), while most do not distinguish among multiple SFSC forms.

Table 3.1. Frequency distribution of structural variables and dependent variable

Structural variables	Abbreviation	Coding	Dimension	Number of observations
Data source	DSOURCE	0	Field survey	29 (60%)
		1	Secondary data	19 (40%)
Duration	DURATION	0	One year	41 (85%)
		1	Multi-year	7 (15%)
Study period	PERIOD	0	[2000-2010]	9 (19%)
		1	[2011-2015]	13 (27%)
		2	[2016-2022]	26 (54%)
Location	LOCATION	0	Europe	14 (30%)
		1	US	34 (70%)
Number of SFSC forms	NSFSC	0	One form of SFSC	12 (25%)
		1	Multiple forms of SFSC	36 (75%)
Data analysis	DANALYSIS	0	No Endogeneity correction	42 (87%)
		1	Endogeneity correction	6 (13%)
Nature of the analysis	NANALYSIS	0	Farm viability	16 (33%)
		1	Comparison with conventional markets	32 (67%)
Types of economic measures	MEASURE	0	Gross income	8 (17%)
		1	Net income	29 (60%)
		2	Profit satisfaction	11 (23%)
Economic effect	EEFFECT	0	Negative or neutral	22 (46%)
		1	Positive	26 (54%)

3.4.2 Empirical model

Using logistic regression, we examine how different structural characteristics are associated with conflicting findings on the effect of SFSC engagement on farm economic performance.

Table 3.2 presents the results, which identify the structural variables that have a statistically significant association with findings of positive economic performance for SFSC participation. The empirical model also reports marginal effects, computed as the difference between the probabilities estimated at the sample means when the outcome variable takes the values 1 and 0, respectively (Table 3.2, column 2). The confusion matrix evaluates the predictive performance of the logistic regression model by comparing the classification of the predicted responses with the effective values of the exogeneous variable in the sample. One of the most common indicators derived from the confusion matrix is accuracy, which is the percentage of correct predictions. Our model made 75% correct/appropriate predictions which is quite good considering the sample size and the number of predictors (Table 3.3).

The structural variables for outcome measure type and location are statistically significant. The profit satisfaction category exhibits a positive and statistically significant value, indicating that studies capturing economic performance with a profit satisfaction measure are more likely to report a positive economic effect of SFSC participation than studies using net or gross income measures. In terms of marginal effects, studies using a profit satisfaction measure are 75.7 percentage points more likely to report that SFSC adoption increases farm performance than studies using the gross income measures. The logistic regression results also reveal that the economic performance of SFSC depends on location. Studies conducted in US are significantly less likely to report positive economic benefits from participating in SFSC than those conducted in Europe. Marginal effects indicate that studies conducted in North America are 48.4 percentage points less likely to report a positive effect of SFSC adoption on farm performance than studies conducted in Europe (or Oceania). Other structural variables in the analysis are not statistically significant.

Table 3.2. Results of the logistic regression analysis of the economic performance benefits of Short Food Supply Chains

	(1) Coefficient estimate	(2) Marginal effect
DSOURCE		
Field surveys	-1.125	-.267
	(1.127)	(.250)
DURATION		
Multi-year	-1.624	-.374
	(1.308)	(.248)
PERIOD		
[2011-2015]	-1.698	-.399
	(1.301)	(.269)
[2016-2022]	-.597	-.132
	(1.161)	(.243)
LOCATION		
US	-2.352**	-.484***
	(1.047)	(.156)
NSFSC		
Multiple forms of SFSC	-1.386	-.311
	(1.143)	(.219)
DANALYSIS		
Endogeneity correction	-.662	-.163
	(1.736)	(.420)
NANALYSIS		
Comparison with conventional markets	.205	.050
	(.928)	(.230)
Types of economic measures		
Net income	1.879	.372
	(1.755)	(.247)
Profit satisfaction	3.982**	.757***
	(1.984)	(.219)
Constant	2.512	
	(2.379)	
Observations	48	
Pseudo R2	.26	
ll	-24.482	
Chi2	17.24	

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 3.3. Confusion matrix

Actual / Values / Predicted Values	Negative	Positive
Negative	14	4
Positive	8	22

3.5 Discussion

Based on far more empirical evidence than previous reviews, this meta-analysis does not establish an unambiguous relationship between SFSC participation and farmer income. However, our meta-analysis does show that the effect of SFSC on farm economic performance varies depending on location and the economic performance indicator used.

Better economic performance of SFSC is more likely in studies conducted in Europe rather than the US. This result does not indicate that all European farmers participating in SFSC are successful. Cesaro et al. (2020) show that SFSC adoption does not significantly affect farm performance in the majority of European member states. Notable exceptions exist, such as in Greece, Slovenia and Croatia where studies find a positive impact of SFSC participation on farm performance (Cesaro et al., 2020). Differences in economic performance between Europe and US might be explained by the specific differences in agricultural and marketing systems between these areas (Kneafsey et al., 2013). For example, lower economic performance found in US may be partly explained by the greater prevalence of CSA farmers than in Europe (7398 farms in US against 2783 in Europe in 2015 and despite there are more farms in Europe (Martinez & Park, 2021; URGENCI, 2016)) who prioritize non-economic motivations more than participants in other forms of local marketing channels (Schoolman, Morton, Arbuckle, & Han, 2021).

It is unclear whether the differences in economic performance between Europe and US might be attributed to differences in the policy support for producers who sell through local markets. At the European level, policy support relies mainly on financial incentives from the Fund for Rural Development (FRD) which has been implemented between 2014 and 2020 to promote investments in facilities for selling and processing agricultural products (Dwyer et al., 2016). Similarly, the

Value-Added Producer Grant Program provides grant funding for agricultural producers in the US to add value to their products through processing and marketing. It is funded by the 2014 Farm Bill devoting investments of US$501.5 million over 5 years in many programs promoting local food production. However, some differences exist in terms of policies promoting local food production. The USDA National Farm to School Program implemented in 2010 directly supports local food purchases in school procurement while the green public procurement (GPP) scheme introduced by the European Commission - to drive food procurement towards more sustainable supply and demand patterns - does not acknowledge territorial criteria. In addition, the EU has recognised the importance of labelling schemes for local products in order to support local farming, an approach that is less prominent in the US (Kneafsey et al., 2013).

We also demonstrate that better economic performance of SFSC is more likely to be found in studies using profit satisfaction rather than gross or net income. This is consistent with Kneafsey et al. (2013), who suggest that farmers' perceptions of their economic performance may differ from measured performance through farm accountancy networks. This might be explained by the fact that subjective rating reflects a broader view of farm performance than objective measures focused on more specific financial indicators. Subjective rating can reflect performance at the household level including income sources beyond the production and marketing of agricultural goods such as from non-farm activities and off-farm work. It could suggest that farmers involved in SFSC might reach a decent living income by compensating their income from agricultural activities with non-agricultural income. Another possible explanation is that selling locally for many producers is a great source of enjoyment and there are benefits for the community that might compensate their relatively low monetary return (Sage, 2003; Silva, Dong, Mitchell, & Hendrickson, 2015).

Our meta-analysis reveals that results from studies focused on a single type of SFSC do not differ significantly from studies considering multiple ones. This is consistent with the literature that does not identify a specific SFSC form that works best for farmers. Some studies demonstrate that farmers using DM have lower economic performance than those using intermediated marketing channels (Bauman, Thilmany, & Jablonski, 2018, 2019). Azima and Mundler (2022) report the

opposite effect while Park et al. (2018) find no significant differences between them. When considering more precise SFSC strategies, some studies report a negative impact for farmers participating in FM and CSA due to high competition, market saturation, consumers' low willingness to pay and inefficiencies in production (Galt et al., 2016; Silva et al., 2015; Uematsu & Mishra, 2016). In contrast, others find that CSA (Jablonski, Sullins, & Thilmany, 2019; LeRoux, Schmit, Roth, & Streeter, 2010) and FM (Hunter, Norrman, & Berg, 2022; Schmit, Jablonski, & Laughton, 2019) achieve highest income or find no significant differences. Govindasamy et al. (1999) and Uematsu et al. (2016) report lowest financial performance for temporal marketing (e.g. roadside stores) and pick-your-own operations since they are available only for certain periods of the year and for certain seasonal products. Uematsu et al. (2016) and Silva et al. (2015) find higher economic performance for farmers selling to local retailers (e.g. regional distributors, local grocery stores, restaurants, and other local retailers).

The absence of significant effect for the few studies that account for selection bias might be explained by the fact that the correction they provide is often inadequate. Two studies account for selection bias only with the nonlinearity of the residuals from the first step model although using an instrument is highly recommended for a more robust identification (Park & Lohr, 2010; Park, Mishra, & Wozniak, 2014). In addition, some studies rely on instruments that might be considered as "bad instruments" which can lead to a bias in the resulting estimates that is much greater than the bias in OLS. Chen et al. (2019) use their endogenous explanatory variables aggregated at the county level (the number of farms adopting direct marketing) as an instrumental variable (IV) because having a large number of participants in DM provides farmers incentives to use this SFSC form. However, this IV clearly violates the exogeneity assumption as it might be confounded with other characteristics of the district encouraging farmers to participate in DM and simultaneously affect farm income. The vitality of the local retail environment is also used as IV and could also be suspected of violating the endogeneity condition (Park, 2015; Park et al., 2018).

3.6 Research and policy implications

Our findings have several implications for future studies addressing the economic consequences of SFSC participation. First, it is crucial to better understand the effect of SFSC participation on farm households' income because it appears to differ from the effect determined through standard farm income measurements. It may also be necessary to investigate whether changes in farm business income are sufficient for reaching conclusions on the well-being of farm households (De Mey et al., 2016; Finger & El Benni, 2021).

Future assessments of farm economic performance in SFSC need to be expanded by taking into consideration additional sustainability indicators. Conducting and coordinating parallel meta-analyses on the social and environmental consequences of these supply chains could also be another avenue for research.

Because of the lack of information in the studies identified, this meta-analysis focuses almost entirely on the influence of structural variables related to study methodology without considering more fundamental contextual variables. Previous research demonstrates that the effect of participation in SFSC on farm performance varies as a function of the SFSC forms and the characteristics of the farmers, farms and the area where the farms are located (Enthoven & Van den Broeck, 2021). There is especially a lack of knowledge on the benefits of scaling up and using organic practices for farmers in SFSC (González-Azcárate, Cruz-Maceín, & Bardají, 2022; Mount, 2012). Although we cannot answer the question whether there is a SFSC scheme that works best, a very few studies have examined more closely the results for specific SFSC forms such that more research is needed. A related aspect that deserves further investigation is farmers' motivations and their link with SFSC types and the governance mechanism behind SFSC initiatives as they are associated with different motivations that might partly explain their differences in economic performance (Rosol & Barbosa, 2021; Schoolman et al., 2021).

Despite these variables not achieving statistical significance in our analysis, we recommend that future studies employ more cautiously regression analysis methods accounting for selection

bias than previous ones. Identifying the potential IV before conducting any survey or considering data from non-standard surveys such as on location could improve the IV used. For example, the distance from the farm operators' home to the nearest large town have been used as an IV because it can influence the likelihood to adopt SFSC without affecting farm performance. In addition, we recommend the use of panel data which could increase the credibility of methods accounting for selection bias by controlling for time-invariant unobservable variables.

Based on our results, policymakers and outreach agencies should be aware that SFSC will not necessarily promote the purely economic performance of farms. However, we suggest that they should continue to recognize and build upon the multifunctional benefits (economic, social and environmental) of these supply chains. If the full set of benefits is considered to be attractive enough, society should consider providing additional resources and support to the producers who participate in these supply chains. Also, because the effect of SFSC participation on farm economic performance is ambiguous, the efficiency of federal support for SFSC must be given careful attention. Policy-makers need to define clear income targets for farmers engaged in SFSC, especially during their start-up phase, and develop appropriate evaluation frameworks in order to assess whether policy measures have achieved their expected outcomes and how they can be improved. In addition, agricultural statistical surveys monitoring farm income and business activities need to collect additional information on farm households' disposable income. They should allow comparable analysis across countries and SFSC schemes by adding similar questions on supply chain participation in terms of marketing forms and level of involvement.

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3.7 References

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3.8 Appendix

Table A3.1. Keywords

Supply chain keywords	Population keywords	Topic keywords	Social science discipline filters
Local food	Farmer	Farmer characteristics:	Web of Sciences
Local market	Producer	Feature	Business Finance
Local supply chain	Rancher	Factor	Business
Alternative food	Grower	Characteristic	Agriculture Multidisciplinary
Short food supply chain		Determinant	Agricultural Economics & Policy
Direct marketing		Driver	Management
Direct-to-consumer		Typology	Political Science
Direct agricultural market		Type	Sociology
Direct sales		Attribute	Economics
Direct selling			Urban Studies
Shortened supply chain		Farmer motivations:	Social Sciences Interdisciplinary
Direct Farm Marketing		Attitude	Regional & Urban Planning
Community supported agriculture Farmers market		Motivation	Geography
		Expectation	Social Issues
Farm-to-school		Willingness	Multidisciplinary sciences
Farm-to-institution		Incentive	Scopus
Innovative marketing		Reason	Business, Management and Accounting
Locally grown		Goal	
			Social Sciences
		Barriers:	Economics, Econometrics and Finance
		Barrier	
		Challenge	Agricultural and Biological Sciences
		Obstacle	
		Constraint	
		Difficulties	
		Struggle	
		Income Impact	
		Profit	
		Income	
		Expenditure	
		Earning	
		Revenue	
		Return	
		Financial	
		Performance	
		Viability	
		Wage	

Table A3.2. The Population, Intervention, Comparison, Outcomes, and Study (PICOS) criteria

Parameter	Inclusion criteria	Exclusion criteria
Population	Farmers	Articles outside the study zone (Europe, Northern America and Australia)
Intervention	Participation in local food system/short food supply chain	
Comparison	Not applicable	Not applicable
Outcomes	Characteristics, motivations, barriers and economic outcomes of farmers involved in SFSC	Articles not responding clearly to the object of research and to its purpose Articles not targeting SFSC
Study design	Both quantitative and qualitative studies	Literature reviews, theses and dissertations, letters, book chapters, reports, authors' comments and other grey literature

Table A3.3. Supply chain abbreviations

Supply chain name	Abbreviation
Alternative food system	AFN
Community supported agriculture	CSA
Direct marketing	DM
Farmers market	FM
Farm-to-institution	FTI
Farm-to-Restaurant	FTR
Long food supply chain	LFSC
Local food system	LFS
Short food supply chain	SFSC
Solidarity purchase group	SPG
Value-based supply chain	VBSC

Table A3.4. Research articles examining the effect of SFSC participation on farm economic performance

	Author	Year	Setting	Supply chain	Farmer sample	Data analysis	Outcome unit	Nature of the analysis	Economic effect of SFSC
1	Govindasamy et al.	(1999)	US	DM	Farmer survey (n= 455 with 79% of farms engaged in retailing). Not representative of general farm population (NR)	Logit model	Profit satisfaction	LFSC comparison	Positive
2	Verhaegen and Van Huylenbroeck.	(2001)	Belgium	Innovative marketing channels	Interviews with actors involved in 6 innovative marketing channels (direct selling (2), co-operatives (2) and labelled traditional marketing channels (2)). NR	Cost–benefit analysis	Net income	LFSC comparison	Positive
3	Govindasamy et al.	(2003)	US	FM	Farmer survey (n= 36) of farms retailing at FM. NR	Logit model	Profit satisfaction	LFSC comparison	Positive
4	Hunt	(2007)	US	FM	Farmer (n=65) and other vendors (n=16) survey of farms marketing through FM. NR	Cluster analysis and probit model	Net income	LFSC comparison	Positive
5	Hardesty and Leff.	(2010)	US	FM, CSA and wholesale	Farmer interviews (n = 3 with 1 farms engaged in FM, 1 in CSA and 1 in wholesale). NR	Cost and return analysis	Net income	LFSC comparison	Negative/Neutral
6	LeRoux et al.	(2010)	US	FM, CSA, Farm stand and U-pick	Farmer interviews (n= 4, with farms marketing trough FM (1), CSA (1), Farm stand (1) and U-pick (1). Farmer survey (n= 14) of farms selling local food. NR	Cost and return analysis	Net income	LFSC comparison	Negative/Neutral
7	Park and Lohr.	(2010)	US	Local selling	Farmer survey (n=817) of farms selling local food. NR	Ordered probit model, Heckmans' method	Gross income	LFSC comparison	Negative/Neutral
8	Lohr and Park.	(2010)	US	Local selling	Farmer survey (n= 787) of farms	Stochastic production	Gross income	LFSC comparison	Negative/Neutral

					engaged in local selling. NR	frontier models			
9	**Detre et al.**	**(2011)**	**US**	**DM**	**ARMS (2002, n =11,303 farms with 3% of the farmers in the sample using DM). R**	**Probit model**	**Gross income**	**LFSC comparison**	**Positive**
10	Schmit and Gómez.	(2011)	US	FM	Vendor survey in 27 FM (n=103) and market manager survey (n= 21). NR	Multinomial logit specification and ordinary least squares (OLS)	Profit satisfaction	Viability	Positive
11	Broderick et al.	(2011)	Australia	Farm-to-restaurant, supermarket and food service distributors, FM, home delivery	Farmer interviews (n=6) of farms engaged in SFSC. NR	Interviews	Net income	Viability	Positive
12	Galt et al.	(2012)	US	CSA	Farmer interviews (n=54) of farms engaged in CSA. NR	Descriptive statistics	Profit satisfaction	Viability	Negative/Neutral
13	Galt.	(2013)	US	CSA	Farmer interviews (n= 54) of farms engaged in CSA. NR	OLS model and interviews	Profit satisfaction	Viability	Negative/Neutral
14	Richard et al.	(2014)	France	SFSC	Farmer survey (n = 507) of farms engaged in SFSC. NR	Descriptive statistics and interviews	Net income	LFSC comparison	Positive
15	Kim et al.	(2014)	US	FM	Price data were collected, yields were provided by the USDA, cost of production are from various studies, Marketing costs are reported by Utah growers using a survey	Simulation model	Net income	LFSC comparison	Positive
16	Park et al.	(2014)	US	DM	ARMS (2008, n = 340 with 10% of the farms in the sample use direct selling). NR	Multinomial logit (MNL) model with selectivity approach	Gross income	LFSC comparison	Negative/Neutral
17	Tudisca et al.	(2014)	Italy	SFSC (Direct sales, FM, e-	Farmer interviews (n=20) of farms	Descriptive statistics	Profit satisfaction	Viability	Positive

				commerce, farm shop, SPG and vending machines)	marketing through AFN. NR				
18	Silva et al.	(2015)	US	CSA, FTI, FTR, wholesale and FM	Farmer survey (n=135 with 60% of the respondents participate in wholesale markets, and less than half market to restaurants or institutions, with 47% using FM and more than 40% using CSA. NR	Multivariate probit model and ordered probit model	Profit satisfaction	LFSC comparison	Negative/Neutral
19	Hu and Shieh.	(2015)	US	Direct sales (« deliviery » to consumers, self-establishment of organic store, sales in private farms, market or on streets, production and marketing groups or cooperating with other farmers) Indirect sales (sales to middleman, production and marketing group, delivery companies, supermarket, organic specialty stores, restaurants and others)	Farmer interviews (n= 274) of farms participating in direct and indirect sales. NR	Analysis of variance	Net income	LFSC comparison	Negative/Neutral
20	Park.	(2015)	US	DM	ARMS (2008-2010, n = 5183 with 646 farms using DM and 4537 not DM). R	Recentered Influence Functions apply on the	Gross income	LFSC comparison	Negative/Neutral

						Unconditional quantile regression model			
21	Tudisca et al.	(2015)	Italy	DM	Farmer survey (n=30) of farms adopting a SFSC strategy. NR	Descriptive statistics	Net income	LFSC comparison	Positive
22	Galt et al.	(2016)	US	CSA	Farmer survey (n= 111) of farms engaged in CSA. NR	Descriptive statistics and correlation analysis	Net income	LFSC comparison	Negative/Neutral
23	Uematsu and Mishra.	(2016)	US	DM	ARMS (2008, n = 4,629 farms). DM strategy includes Roadside stores (n =161), direct sales to local grocery stores, restaurants, or other retailers (n =153), FM (n = 118), Regional distributors (57) and CSA (12). R	Quantile regression	Gross income	LFSC comparison	Negative/Neutral
24	Mundler and Laughrea.	(2016)	Canada	SFSC	Farmer survey (n=32) of farms engaged in SFSC. NR	Descriptive statistics compared to national averages	Net income	LFSC comparison	Negative/Neutral
25	Morel et al.	(2017)	France	DM	Farmer interviews (n= 20) of farms engaged in DM. NR	Stochastic Modeling	Viability	LFSC comparison	Positive
26	Bauman et al.	(2018)	US	DM	ARMS (2013, n= 17 474 farms with 1,013 selling local food). R	Descriptive statistics	Net income	LFSC comparison	Positive
27	Park et al.	(2018)	US	DM	ARMS (2008-2010, n = 5,959 farmers with 234 farms using only direct to consumers, 157 using only direct to retailers and 180 using both direct to retailers and consumers). R	Multinomial treatment effect model	Gross income	LFSC comparison	Negative/Neutral

28	Khanal et al.	(2018)	US	DM	ARMS survey (2012, n = 18,728 farmers) with 5.4% using direct selling. R	Unconditional quantile regression	Net income	LFSC comparison	Negative/Neutral
29	Morckel.	(2018)	US	FM	Farmer survey (n= 45) of farms engaged in FM. NR	Descriptive statistics	Profit satisfaction	Viability	Positive
30	Schmit et al.	(2019)	US	DM	Farmer sample (n= 67 with 47 farms using DM). NR	Means difference tests	Net income	LFSC comparison	Positive
31	Bauman et al.	(2019)	US	Direct-to-consumer and local sales from on-farm store, u-pick, roadside stands, CSAs and FM; local retail outlet such as a restaurant or grocery store; Regional distributor such as food hub; Local institutions such as school or hospital	ARMS (2013-2014, n= 44 536 with 2624 farms selling local food). R	Stochastic profit frontier model	Net income	LFSC comparison	Negative/Neutral
32	Brekken et al.	(2019)	US	Values-Based Supply Chain (VBSC) and DM	Farmer survey (n= 182) of farms engaged in VBSC. NR	TOA-MD Simulation	Net income	LFSC comparison	Positive
33	Chen et al.	(2019)	US	DM	ARMS (2012, n= 14960 with 7.17% of farms adopting DM). R	Bivariate binary choice model	Gross income	LFSC comparison	Negative
34	Malak-Rawlikowska et al.	(2019)	Europe	SFSC (pick your own, sales to individual consumers, Internet deliveries, delivery to consumer, FM,	Farmer survey (n=186 with 65% of farms engaged in SFSC) NR	Descriptive statistics	Net income	LFSC comparison	Positive

				Sales to small retail outlets (one intermediary))					
35	Sroka et al.	(2019)	Germany	DM	Farmer survey (n=199 with 56 using DM). NR	Classification and regression trees	Profit satisfaction	LFSC comparison	Positive
36	Paul.	(2019)	US	CSA	Farmer interviews (n=16) of farms engaged in CSA. NR	Interviews	Net income	LFSC comparison	Positive
37	Clark.	(2020)	US	On-farm selling	Case study on one farm. NR	Cost and return analysis	Viability	Net income	Negative
38	**Jablonski et al.**	**(2020)**	**US**	**SFSC (FM, roadside stands, and u-pick), Intermediated channels (direct to restaurants, institutions, or to regional aggregators)**	**USDA ARMS (2013–16 , n = 78,559 farms) of farms selling local or non-local food. R** **Samples include 73,191 (positive labor expenditure) and 26,694 (positive wage) producers without local sales and 3,899 (positive labor expenditure) and 1,569 (positive wage) producers with local food sales**	**Descriptive statistics**	**Net income**	**LFSC comparison**	**Positive**
39	Mundler and Jean-Gagnon.	(2020)	Canada	SFSC	Farmer survey (n=32) of farms involved in SFSC. NR	Descriptive statistics compared to national averages	Net income	LFSC comparison	Negative/Neutral
40	Alonso Ugaglia et al.	(2020)	France	SFSC	Farmer interviews (n=48) of farms engaged in SFSC. NR	Interviews	Net income	Viability	Positive
41	Hochuli et al.	(2021)	Switzerland	DM	Agroscope annually surveys (n = 3500 dairy farms with 1019 using DM). R	Descriptive statistics and non-parametric test	Net income	LFSC comparison	Negative/Neutral

42	Medici et al.	(2021)	Italy	CSA	Interviews (n = 19 CSA). NR	Descriptive statistics	Profit satisfaction	Viability	Positive
43	Floris	(2021)	Slovakia	SFSC	Farmer survey (n= 43 with 17 in SFSC)	Descriptive statistics	Net income	LFSC comparison	Positive
44	Jablonski et al.	(2022)	US	LFS	USDA ARMS (2013–2016, n = 3,908 beginner farmers using LFS).NR	Descriptive statistics	Net income	viability	Positive
45	Azima et al.	(2022)	Canada	DM	Farmer survey (n=613 farms using DM). NR	OLS controlling for endogeneity	Profit satisfaction	Viability	Positive
46	Hunter et al.	(2022)	Swedish	SFSC	Farmer survey (n=286 farms involved in SFSC) NR	Bi-variate correlations	Net income	viability	Negative/Neutral
47	Dono et al.	(2022)	Italy	DM	Farm accountancy data network (FADN, 2014-2016, n = 4612 with 17.6% of farms using DM) NR	Descriptive statistics, parametric and non-parametric test	Net income	LFSC comparison	Negative/Neutral
48	Floriš et al.	(2022)	Slovakia	DM	Farmer survey (n = 43 farms with 17 involved in SFSC) NR	Descriptive statistics	Profit satisfaction	LFSC comparison	Positive

Chapter 4

Do Farmers Participating in Short Food Supply Chains Use Less Pesticides? Evidence from France

This work is joint with Sophie Drogué and Florence Jacquet

Abstract

Proponents of short food supply chains (SFSC) have lauded their environmental benefits. Nevertheless, most studies on SFSC have focused on their climate impact, while the synthetic pesticide use by farmers participating in SFSC has received little research attention. In this study, we investigate the effect of farmers' involvement in different SFSC channels on synthetic pesticide use and crop yields. This study relies on data obtained from the 2020 French agricultural census and a 2018 French national survey on the phytosanitary practices of representative market gardeners. This paper uses a multinomial endogenous treatment effect model in order to account for endogeneity. We demonstrate that the effect of SFSC participation on farmers' synthetic pesticide use varies depending on the type of SFSC channel employed. Farmers who sell part of their vegetable crops through direct-to-consumer (DTC) channels use significantly fewer synthetic pesticides than those who only sell their crops through long food supply chains (LFSC). However, there is no evidence that farmers involved in direct-to-retailer (DTR) channels use significantly fewer synthetic pesticides. In addition, we have not found any evidence that SFSC participation decreases crop yields.

Résumé

Les partisans des circuits courts (CC) ont loué leurs avantages environnementaux. Néanmoins, la plupart des études sur les CC se sont concentrées sur leur impact climatique, tandis que l'utilisation de pesticides de synthèse par les agriculteurs participant aux CC a reçu peu d'attention de la part des chercheurs. Dans cette étude, nous examinons l'effet de l'implication des agriculteurs dans différents types de CC sur l'utilisation des pesticides de synthèse et le rendement des cultures. Cette étude s'appuie sur des données issues du recensement agricole français de 2020 et d'une enquête nationale française de 2018 sur les pratiques phytosanitaires de maraîchers représentatifs. Cet article utilise un modèle multinomial à effet de traitement endogène afin de tenir compte de l'endogénéité. Nous démontrons que l'effet de la participation en CC sur l'utilisation de pesticides de synthèse par les agriculteurs varie en fonction du type de CC utilisé. Les agriculteurs qui vendent une partie de leurs cultures maraîchères par l'intermédiaire de canaux de vente directe au consommateur (DTC) utilisent nettement moins de pesticides synthétiques que ceux qui ne vendent leurs cultures que par l'intermédiaire de chaînes longues d'approvisionnement alimentaire (LFSC). Cependant, rien ne prouve que les agriculteurs impliqués dans les circuits de vente directe aux détaillants (DTR) utilisent beaucoup moins de pesticides de synthèse. En outre, nous n'avons trouvé aucune preuve que la participation aux CC diminue les rendements des cultures.

4.1 Introduction

In the European Union, short food supply chains (SFSC) refer to supply chains with "*a reduced number of intermediaries*", generally involving no more than one intermediary from the producer to the consumer (Regulation (EU) No 1305/2013). SFSC have garnered increasing interest from academia and policymakers in tandem with the growing concern of consumers about food provenance and quality and the increasing pressure on the value captured by farmers in conventional supply chains (Marsden et al., 2000; Renting et al., 2003). A growing number of farms in Europe have chosen to market through these alternative food networks (European Parliament, 2016), particularly in France, where 23% of farms participated in SFSC in 2020 (AGRESTE, 2020)[12]. SFSC development has been supported by the European Union (EU) through the European Agricultural Fund for Rural Development, which devotes up to 10% of its expenditures to the promotion of food chain organization (Dwyer et al., 2016).

Proponents of SFSC have lauded their sustainable benefits, but the "local trap" critique argues that they are not inherently more desirable than conventional supply chains (Born & Purcell, 2016). In particular, research has called into question their positive impact on farm viability because of their high costs and labor requirements (Chiaverina et al., 2023), and critics have pointed to their social embeddedness as being the preserve of white, educated and wealthy customers (Brown et al., 2009; Hinrichs, 2000; Hinrichs & Allen, 2008). Regarding environmental sustainability, most studies have focused on greenhouse gas emissions issued from SFSC and report mixed evidence (Coley et al., 2011; Edwards-Jones, 2010; Edwards-Jones et al., 2008).

[12] SFSC comparisons between European member states are limited, because national data that are collected on SFSC in comparable ways are scarce (Enthoven & Van den Broeck, 2021). Direct-to-consumer (DTC) channel comparisons are possible but not direct-to-retailer (DTR) channel comparisons because most countries have no data whatsoever on them (Enthoven & Van den Broeck, 2021). The average number of farms marketing through DTC channels for Austria, Belgium, France, the Netherlands and Switzerland amounts to 15.8% of total farms in 2016 (Enthoven & Van den Broeck, 2021).

Such inconclusiveness on the socio-economic and environmental impacts of SFSC calls for further objective research relying on strong theoretical grounding and quantitative rigor (Malak-Rawlikowska et al., 2019; Stickel & Deller, 2014). In particular, certain aspects of the environmental impact of SFSC, such as the use of synthetic pesticides by participating farmers, have received little research attention. Only a few studies conducted in the US and Asia examine the impact of SFSC participation on the use of synthetic pesticides and report lower synthetic pesticide use by farmers involved in SFSC (Lee et al., 2020; Schoolman, 2019; Zhang et al., 2019; Zhang & Yu, 2021).

Scientific studies have consistently revealed that pesticides are responsible for numerous harmful environmental and human health consequences (Carvalho, 2017; Geiger et al., 2010). Nevertheless, pesticide use has continued to increase globally (Zhang, 2018), and the numerous pesticide policies introduced by European member states have not been successful in reaching their pesticide usage reduction goals (Bjørnåvold et al., 2022; Hossard et al., 2017; Lamichhane et al., 2016; Möhring et al., 2020). Pesticide dependency is not only a technological issue for farmers, but also a socio-economic one involving multi-actors and multi-factors that policy frameworks should further consider in order to improve their effectiveness (Hu, 2020; Nagesh et al., 2023). Public support of SFSC could be a lever to overcome some of the socio-economic obstacles to the adoption of pesticide alternatives. We identify in the literature three mechanisms of SFSC that could have an effect on reducing synthetic pesticide use.

First, reducing synthetic pesticide use is not always an easy choice for farmers (Lee et al., 2019; Runhaar et al., 2017). The adoption of more sustainable farming practices is hampered by socio-economic, institutional and political constraints (e.g., product quality demands; economic constraints from marketing firms and regulations; lack of technical knowledge; unavailability of agroecological inputs occurring along the whole food value chain) (Boulestreau et al., 2021; Cowan & Gunby, 1996; Guichard et al., 2017; Jacquet et al., 2022; Magrini et al., 2016; Meynard et al., 2018; Togbé et al., 2012; Vanloqueren & Baret, 2008; Wilson & Tisdell, 2001). In particular, farming practices are strongly framed by the constraints of long food supply chains (LFSC), namely constraining farmers to produce large volumes of a few crops while complying with high marketing

standards under price and competition pressure. Such specifications may encourage farmers to adopt, and lock them into, unsustainable farming practices (Burch et al., 2013; Lefèvre et al., 2020; Milford et al., 2021; Navarrete, 2009; Zwart & Wertheim-Heck, 2021). For example, farmers are constrained by retailer requirements and consumer preferences to produce fruits and vegetables with a high cosmetic standard (e.g., minimal pest damage and optimal size and color development), which often requires the use of synthetic pesticides (Pimentel et al., 1993; Yue et al., 2009; Zakowski & Mace, 2022). In contrast, SFSC marketing requirements are less standardized, offering more opportunities and autonomy to implement ecologically sound practices (Bressoud, 2010; Lefèvre et al., 2020; Marechal & Spanu, 2010; Milford et al., 2021; Navarrete, 2009). SFSC are more likely to adopt pest- and disease-resistant crop varieties that require lower pesticide dependence, as farmers are not constrained by retailer preferences for more established varieties and seeds (Finger et al., 2022; Zhang et al., 2019).

Second, the development of more environmentally-friendly farming practices depends on the capacity of farmers to be economically competitive (Crowder & Reganold, 2015; Reganold & Wachter, 2016; Rosa-Schleich et al., 2019; Sutherland et al., 2012). Farmers involved in SFSC can make their alternative farming practices financially viable by capturing a value-added premium generated by the reconnection between producer and consumer based on shared goals and values (Mount, 2012; Mount & Smither, 2014; Verhaegen & Van Huylenbroeck, 2001). The tangible and intangible qualities of their products (e.g., authenticity, safety and trust), which allow these farmers to command a price premium, are more easily recognized when the connection between farmers and consumers is closer (Mount, 2012; Verhaegen & Van Huylenbroeck, 2001). This price premium is crucial as it enables farmers to keep up with the disadvantages of potential yield losses associated with the adoption of reduced synthetic pesticide farming practices. The closer relationship between farmers and consumers can even be considered as a substitute for organic certification (Dabbert et al., 2014; Flaten et al., 2010; González-Azcárate et al., 2022; Higgins et al., 2008; Veldstra et al., 2014), as it builds up trust and reduces information asymmetry between farmers and consumers, thus convincing consumers that the products are as good as organic-certified alternatives. As such,

farmers engaged in SFSC can benefit from a higher premium than that fetched by certified organic products, without the financial, administrative and time burdens associated with certification (Onozaka & McFadden, 2011; Veldstra et al., 2014).

Finally, farmers' pest management decisions are strongly dependent on decisions made on neighboring farms, which highlights the importance of peer interactions among farmers (Bakker et al., 2021; Läpple & Kelley, 2015; Stallman & James, 2015). A positive experience with the adoption of alternative pest control methods (e.g., reduced tillage) can be used as a model for farmers who belong to the same network and enhance their intentions to adopt the same methods (Bakker et al., 2021; Stallman & James, 2015). Participation in certain types of SFSC, such as farmers' markets and box schemes, can develop social interactions between farmers based on technical dialogue and support. Such learning connections among farmers developed through the market can provide them with shared values and experiences that can promote the consideration and practice of more sustainable farming (Chiffoleau, 2009; Chiffoleau et al., 2016; Jarosz, 2000; Lamine et al., 2009; Marechal & Spanu, 2010; Zoll et al., 2021).

The impact of SFSC on different social, economic and environmental aspects varies across SFSC types (Enthoven & Van den Broeck, 2021; Forssell & Lankoski, 2015; Malak-Rawlikowska et al., 2019; Schmutz et al., 2018); however, most studies evaluating SFSC sustainability do not take into account their variety (Aubry & Kebir, 2013; Lamine et al., 2019). Producers using direct-to-consumer (DTC) chains, such as farmers' markets or on-farm sales, sell directly to consumers without any third-party actor. This close contact with customers allows farmers to keep a greater share of their sales revenues but adds labor and marketing costs and limits scalability (Renkema & Hilletofth, 2022). By introducing just one intermediary that connects producers and consumers, such as a distributor, canteen or supermarket, direct-to-retailer (DTR) chains might be a means of resolving these challenges (Dimitri & Gardner, 2019; Rosol & Barbosa, 2021). Over the past decade in France, the share of farms using DTR chains has risen from 5.3% to 11.2% (AGRESTE, 2020, 2010). DTR channels have also experienced a boom in the US (Low et al., 2015), because they are

more conveniently located and offer more complementary food products than DTC channels do (Printezis & Grebitus, 2018; Richards et al., 2017).

However, DTR channels have the potential to reproduce the conventionalization seen in the organic product market by involving mainly large-scale producers with primarily economic motivations. Increased scale and competition in DTR channels can challenge the capacity of farmers to capture a premium and can force them to adopt more intensive farming practices (Ilbery & Maye, 2006; Mount, 2012; Mount & Smither, 2014; Rosol & Barbosa, 2021). Indeed, farmers participating in DTR chains still have to comply with stringent marketing requirements that reward these intensive farming practices (Zwart & Wertheim-Heck, 2021). Mount and Smither (2014) show qualitatively that farmers participating in DTR chains adopt farming practices that are close to those used in LFSC. Considering all SFSC types to be the same – particularly DTC and DTR channels – might therefore blur the effect of SFSC on synthetic pesticide use because it combines what could be opposing results of these different SFSC types.

The objective of this paper is to investigate the effect on synthetic pesticide use of different strategies of SFSC involvement in vegetable production, depending on the presence or absence of an intermediary. In particular, we consider the impact on synthetic pesticides occurring from participating in (i) DTC channels, (ii) DTR channels and (iii) a combination of both DTC and DTR channels, compared to participation only in LFSC. In addition, we examine the effect of these different SFSC strategies on crop yields in order to evaluate the efficiency of their associated farming practices. Low-pesticide production practices can lead to lower yields due to competition from weeds or crop damage caused by pests and diseases (Foley et al., 2011; Tuomisto et al., 2012). Two studies conducted in China show that market gardeners engaged in SFSC have a lower level of synthetic pesticide dependency and higher yields thanks to the use of improved seed and capital-intensive technologies (Zhang et al., 2019; Zhang & Yu, 2021).

To answer this research question, this study relies on data obtained from the 2020 French agricultural census and a national survey on the phytosanitary practices of market gardeners conducted in 2018. One reason for focusing on market gardeners is that vegetables are the most

frequently represented products in SFSC (Uematsu & Mishra, 2016). The main concern when evaluating the impact of farmers' participation in SFSC on their synthetic pesticide use and crop yields is that it may be the result of some omitted variables. Unobservable or unidentified variables characteristics might affect the decisions both to adopt SFSC and to use synthetic pesticides (or not), leading to spurious estimates of the impact of SFSC participation on synthetic pesticide use and crop yields. To address this issue, this paper employs a multinomial endogenous treatment effect model proposed by Deb and Trivedi (2006) that accounts for selection bias and endogeneity originating from observed and unobserved heterogeneity.

The paper is structured as follows. The two following sections define the data and methodological approach used to evaluate the effect of SFSC participation on the application of synthetic pesticides and yields by farmers. The results of the analysis are presented in Section 4.4 and discussed in Section 4.5.

4.2 Data

This study relies first on data obtained from a national survey on the phytosanitary practices of representative market gardeners, conducted in 2018 by the French Ministry of Agriculture Department of Statistics. The survey initially involved 7,323 parcels of carrots, cabbages, strawberries, melons, leeks, tomatoes and lettuces[13]. In this survey, information is at the parcel or farm level, depending on the nature of the variable examined. In addition, we employ data from the 2020 French agricultural census, which provides complementary information about the socio-economic and production characteristics of vegetable farms. We match the data from the two surveys presented above, thanks to the business identification number assigned to each farm. We end up with a sample of 4,740 market gardeners. Figure A4.1 in the Appendix provides the municipal location of the farms investigated.

[13] Strawberries and melons are classified as vegetables in this survey

4.2.1 Explanatory variables

The 2020 French agricultural census gathered information from market gardeners on the SFSC types they used to sell their products. Based on this information, a set of four marketing channel strategies were identified according to the presence or absence of an intermediary (Figure 4.1). Market gardeners using only LFSC to sell their vegetables are considered as the reference group and represented 54.3% of market gardeners. The second group, —using DTC channels — included 24.3% of the market gardeners who sold directly to consumers without any third-party actor. This group covers market gardeners involved in the following SFSC types: (1) on-farm selling, (2) door-to-door selling, (3) farmers' markets, (4) collective selling points, (5) community supported agriculture, and (6) online selling. The third group—using DTR channels—accounted for 4.9% of the market gardeners; these market gardeners sell through one intermediary organization that connects producers and consumers. It includes the following SFSC types: (1) direct sales to retailers, (2) direct sales to large stores (3) direct sales to restaurants and (4) direct sales to institutions. The fourth group included 16.4% of the market gardeners who use both DTC and DTR channel types. Note that market gardeners engaged in the various SFSC strategies defined above may also sell a minor amount of their production through LFSC[14]. The literature has shown that many farmers combine SFSC with LFSC (Filippini et al., 2016a, 2016b; Gilg & Battershill, 1998; Thomé et al., 2021).

[14] For example, farmers might sell their vegetables through DTC channels and LFSC, DTR channels and LFSC or a combination of DTC sales, DTR sales and LFSC.

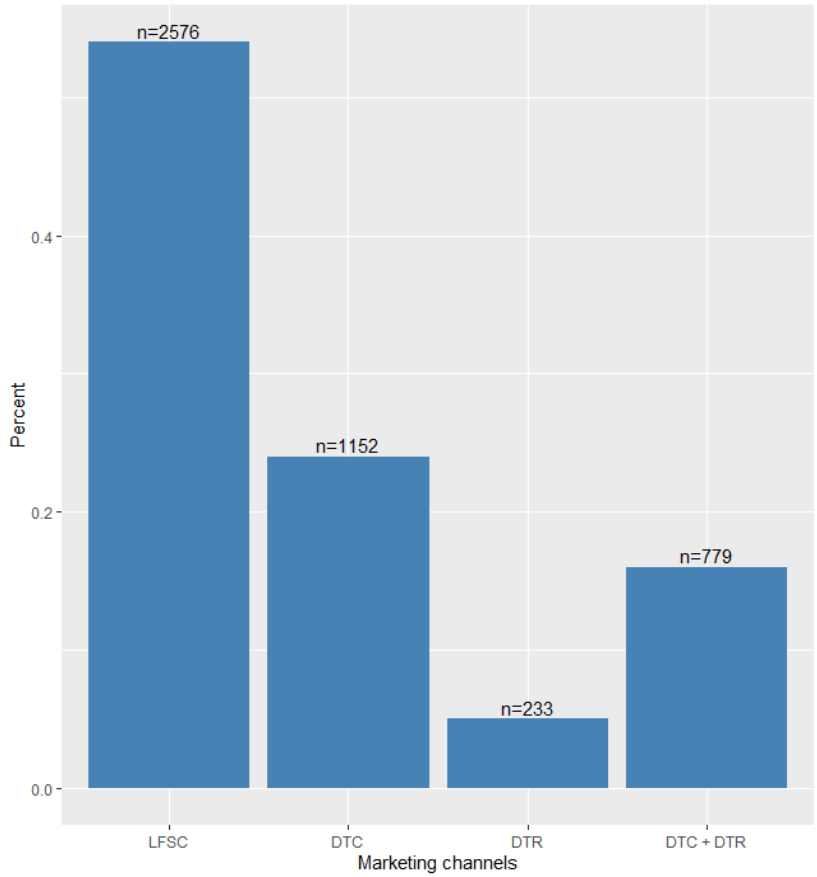

Figure 4.1. An overview of the different SFSC channel strategies involved in this study

A key part of defining the appropriate counterfactual condition is clarifying precisely what is held constant while the variable of the marketing channel strategy changes (King et al., 1994). Thus, we controlled for a variety of agronomic, social and economic variables affecting both the decision to participate in SFSC and the decision to use synthetic pesticides (see Table A4.1 in the Appendix). These control variables are from both the 2020 French agricultural census and the 2018 French survey on the phytosanitary practices of market gardeners. They include controls for characteristics of the farms' production and farming practices (land use, diversification activities, diversification species, quality labels, organic farming) and of the farm manager (age, gender and education). We also controlled for crops grown and the presence of pest and disease problems on the surveyed parcels. In addition, we included regional effects for 10 administrative regions, accounting for regional differences in farm structure, agronomic conditions, marketing constraints, etc.

4.2.2 Dependent variables

The Treatment Frequency Index (TFI) is our dependent variable, measuring the use of synthetic pesticides on the surveyed parcels. This index represents the ratio between the applied and recommended doses, considering the area of the treated parcels (Pingault et al., 2009). For example, if the reference dose of an herbicide is spread over the entire area of a plot, then the TFI of the plot equals one. The annual TFI of the entire parcel is the sum of the TFI calculated for each treatment performed on the parcel during a crop season:

$$TFI = \sum \frac{applied\ dose}{reference\ dose} * \frac{treated\ area}{total\ area} \quad (4.1)$$

Figure 4.2 reports the median value of the TFI (log-transformed) by crop and marketing channel[15]. Figure 3 reports the median value of the yields (log-transformed) in tons per hectare, by crop and marketing channel. Both TFI and yields are analyzed using the nonparametric Kruskal-Wallis test in order to detect significant differences among marketing channels. For each vegetable, we find that farmers engaged in the three different SFSC strategies have a significantly lower median TFI at the 1% level than do farmers using only LFSC. The only exception is for market gardeners producing cabbage for DTR channels, who have a significantly higher median TFI than those using only LFSC. In addition, market gardeners involved in DTC chains or combining DTC and DTR channels exhibit the lowest synthetic pesticide use. In contrast, the link between SFSC and vegetable production yields is not evident and depends on the crop. The objective of this study is to assess the extent to which differences in synthetic pesticide use and crop yields is attributable to SFSC participation.

[15] We use the log-transformation of the TFI and yields to deal with skewness.

Figure 4.2. Synthetic pesticide use difference (TFI log-transformed) between marketing channels.

Note: Distribution of the TFI for the seven crops and four marketing channels. The p-value indicates the probability that the median for each crop is different between marketing channels (*** p<0.01, ** p<0.05, * p<0.1, Kruskal-Wallis test). n indicates the number of parcels for which the indicators (TFI) have been calculated. The colored boxes indicate the second and third quartiles, with the median represented as a vertical bar within them. The whiskers indicate the largest values which are not farther than 1.5 times the interquartile distance from the boxes. Outliers, which are individual points beyond the whiskers, are not plotted in order to improve the reading of the p-values on the figures.

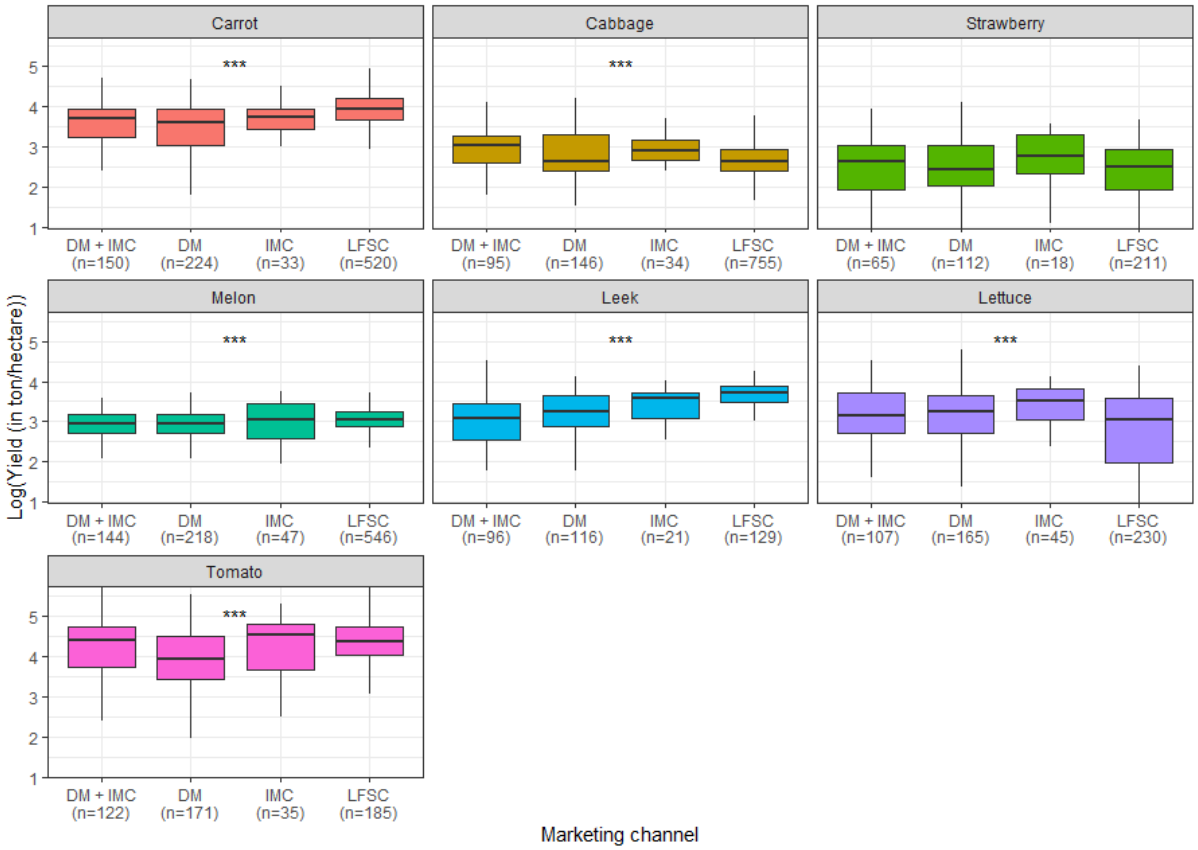

Figure 4.3. Yields (log-transformed), by marketing channel and crop.

Note: Distribution of yields for the seven crops and four marketing channels. The p-value indicates the probability that the median for each crop is different between marketing channels (*** p<0.01, ** p<0.05, * p<0.1, Kruskal-Wallis test). n indicates the number of parcels for which the indicators (yields) have been calculated. The colored boxes indicate the second and third quartiles with the median represented as a vertical bar within them. The whiskers indicate the largest values which are not farther than 1.5 times the interquartile distance from the boxes. Outliers, which are individual points beyond the whiskers, are not plotted in order to improve the reading of the p-values on the figures.

4.3 Conceptual and econometric framework

Farmers engaged in SFSC are not randomly assigned and often self-select to participate. SFSC participation may therefore be endogenous, due to unobserved or unidentified variable factors affecting farmer adoption of SFSC categories and correlated with synthetic pesticide use and crop yields.

In particular, farmers engaged in SFSC exhibit non-economic motivations such as the political motivation of supporting alternative agriculture methods (Alkon, 2008; Beingessner & Fletcher, 2020; Schoolman et al., 2021), personal and philosophical motivations associated with changing individual life-work balance, as well as the desire to do something more meaningful (Bruce, 2019; Fleury et al., 2016; Ngo & Brklacich, 2014), motivations linked to the enjoyment of

meeting and getting to know customers (Fielke & Bardsley, 2013; Montri et al., 2021) and environmental motivations resulting from ecological concerns (Fleury et al., 2016; Izumi et al., 2010; Leiper & Clarke-Sather, 2017; Newsome, 2020). In addition, farmers who are not primarily driven by economic goals are more likely to reduce their use of synthetic pesticides (Bakker et al., 2021; Chèze et al., 2020; Howley, 2015; Läpple & Rensburg, 2011; Stallman & James, 2015). Thus, we expect that market gardeners with non-economic motivations are more likely to implement reduced synthetic pesticide farming practices and adopt SFSC.

Although the effect of SFSC participation is expected to be biased downward because synthetic pesticide use is estimated without taking account of farmers' motivations, it could be also biased upward without controlling for farmers' risk aversion in our regression model. Some studies argue that SFSC are a risk management tool for farmers, providing them with additional marketing opportunities (Kim et al., 2014; Kneafsey et al., 2013; LeRoux et al., 2010; Paul, 2019; Uematsu & Mishra, 2016; Zhang et al., 2019). Synthetic pesticides are also conventionally considered as risk-reducing inputs, as they help farmers to protect their crops from pest and disease damage (Bontemps et al., 2021; Chèze et al., 2020; Serra et al., 2008). Risk averse producers have been found to be less likely to adopt organic or reduced synthetic pesticide farming practices, because they lead to greater variability in yield and cost (Bontemps et al., 2021; Chèze et al., 2020; Serra et al., 2008). We therefore expect that more risk averse market gardeners are less likely to implement reduced synthetic pesticide farming practices and more likely to adopt SFSC. Unambiguously predicting the direction of omitted variable bias is therefore impossible due to the presence of many omitted variables whose effect on the dependent variable is not of the same sign (Basu, 2018).

Using ordinary least squares (OLS) regression to estimate the SFSC participation effect on synthetic pesticide use would result in an inconsistent estimation. To disentangle the pure effects of SFSC adoption, we adopted a multinomial endogenous treatment effect model proposed by Deb and Trivedi (2006). This two-stage model allows us to account for both self-selection and the interdependence of adoption decisions. In our model, the choice of marketing channel is the treatment, and synthetic pesticide use and yields are the observed outcome measures. In the first

stage, the adoption decision is modelled by a mixed multinomial logit selection model. In the second stage, OLS is used with selectivity correction to estimate the impacts of SFSC participation on synthetic pesticide use and crop yields.

4.3.1 Multinomial endogenous treatment effects model

The multinomial endogenous treatment effects model involves two stages. In the first stage, a farmer makes its marketing decision from a set of four marketing channel alternatives. Following Deb and Trivedi (2006), let V_{ij}^{*} denote the indirect utility obtained by farmer *i* in choosing the j_{th} marketing decision, $j = 0,1,2,3$:

$$V_{ij}^{*} = z_i'\alpha_j + \sum_{j=1}^{J} \delta_{jk} l_{ik} + \varepsilon_{ij} \tag{4.2}$$

Where z_i is a vector of covariates with associated parameters, α_j; ε_{ij} are independently and identically distributed error terms; l_{ik} is the latent factor that includes unobserved characteristics common to farmer $i's$ treatment choice and the outcome variables, such as farmers' non-economic motivations and risk aversion. Let $j = 0$ denote the control group (farmers using only LFSC) and we normalize the indirect utility function to zero for this base choice so that V_{ij}^{*} = 0. Since l_{ik} is not observed, we use the binary variables d_j to represent the observed farmers' marketing decisions. The d_j measures follow a mixed multinomial logit (MNL) structure and $d_i = (d_{i1}d_{i2}, \dots, d_{ij})$. The probability function for the marketing choice is modelled by a mixed multinomial logit structure defined as:

$$Pr(d_i|\, z_i l_i) = \frac{exp(z_i'\alpha + l_{ij})}{1 + \sum_{k=1}^{J} exp(z_i'\alpha_k + l_{ik})} \tag{4.3}$$

We note that the mixed multinomial logit model involves the independence of irrelevant alternatives, implying that the choice between any marketing category is independent of the occurrence of a new marketing option.

The equation for the expected outcomes (TFI and crop yields) in the second stage is:

$$E(y_i|d_i, x_i, l_i) = exp\left\{x_i'\beta + \sum_{j=1}^{J}\gamma_j d_{ij} + \sum_{j=1}^{J}\lambda_j l_{ij}\right\} \tag{4.4}$$

Where γ_i is the synthetic pesticide outcome or crop yield outcome for farmer i and x_i represents exogeneous covariates with parameter vectors β. Parameters γ_j denote the treatment effects relative to the non-adopters. $E(y_i|d_i, x_i, l_i)$ is a function of the latent factors l_{ij} when the outcome variable is affected by unobservable variables that also affect the choice of marketing channel. When λ_j, the factor loading parameter, is positive (negative), treatment and outcome are positively (negatively) correlated with unobserved variables, that is, there is a positive (negative) selection. We assume that the outcome variables follow a normal distribution. The model was estimated using a Maximum Simulated Likelihood approach.

For a more robust identification, Deb and Trivedi (2006) recommend using as exclusion restrictions selection instruments that directly affect the selection variable but not the outcome variable. However, this is not strictly required here, as the parameters of the semi-structural model are, in principle, identified through the nonlinear functional form of the selection model. The instrument used was the distance between the farm operators' home and the nearest city of 20,000 or more inhabitants. Urban areas provide better conditions for SFSC development by offering opportunities to reach more consumers with higher purchasing power and skills. We expect that the distance to the nearest city with a population of 20,000 or more to have no influence on synthetic pesticide use. Note that we do not use this instrument variable (IV) for a more robust estimation of the effect of SFSC on crop yields, because we guess that the proximity to urban areas is correlated with parcel yields.

There is no formal test for the validity of exclusion restrictions in a nonlinear setting (Deb and Trivedi, 2006). Following Di Falco, Veronesi and Yesuf (2011), we performed a simple falsification test where candidate IV may affect the SFSC alternatives but has no influence on synthetic pesticide use among the non-adopting farmers. Results show that the nearest distance to a city of 20,000 or more can be considered as a valid instrument: it is statistically significant in equations of the adoption of SFSC strategies (Table 4.1) but not in equations of synthetic pesticide use (Table A4.2 in the Appendix).

4.4 Results

We present the results in two parts. In the first part, we present the determinants of the different strategies of SFSC involvement (DTC channels, DTR channels and a combination of DTC and DTR channels) (Table 4.1). In the second part, we discuss the effect of the different SFSC involvement strategies on the application of synthetic pesticides and crop yields (Table 4.2 and Table 4.3).

4.4.1 SFSC strategy determinants

Table 4.1 presents parameter estimates of the mixed multinomial logit model of the different SFSC channels. The reference category includes farmers involved only in LFSC, against which the results are compared. We discuss the variables that are relevant to understand the environmental sustainability of farming practices.

Table 4.1. Mixed multinomial logit estimates of the determinants of adoption of each SFSC channel in market gardening (relative to adopting only LFSC)

Variables	(1) DTC channels	(2) DTR channels	(3) DTC + DTR channels
Cabbage	-0.896***	-0.256	-0.751***
	(0.168)	(0.311)	(0.191)
Strawberries	0.0785	-0.365	-0.257
	(0.273)	(0.445)	(0.294)
Melons	0.550**	-0.158	0.406
	(0.247)	(0.393)	(0.258)
Leeks	-0.00570	0.355	0.255
	(0.197)	(0.336)	(0.213)
Lettuces	-0.721***	-0.152	-0.673***
	(0.210)	(0.353)	(0.231)
Tomatoes	-0.00810	-0.179	-0.177
	(0.250)	(0.383)	(0.258)
Log(Size)	-0.800***	-0.417***	-0.640***
	(0.0435)	(0.0663)	(0.0442)
ORG	0.419***	0.269	1.154***
	(0.144)	(0.218)	(0.136)
DIVSPE	3.504***	1.635***	3.253***
	(0.223)	(0.327)	(0.237)
DIVACT	0.385*	0.515*	0.572***
	(0.200)	(0.276)	(0.203)
LABEL	-1.206***	-0.661	-0.854**
	(0.349)	(0.438)	(0.383)
PEST	0.382	0.489	-0.0974
	(0.282)	(0.368)	(0.338)
FEMALE	0.700***	-0.492*	-0.111
	(0.136)	(0.265)	(0.168)
HIGHSCHOOL	-0.180	-0.225	0.295**
	(0.134)	(0.219)	(0.138)
BACHELOR	0.434**	0.251	0.533**
	(0.199)	(0.305)	(0.209)
MASTER	-0.0943	0.130	0.370*
	(0.199)	(0.315)	(0.203)
AGE	-0.00874*	-0.00612	-0.0330***
	(0.00495)	(0.00756)	(0.00534)
DISTANCE	-0.0179***	-0.0252***	-0.0156***
	(0.00384)	(0.00711)	(0.00443)
Region fixed effects	Yes	Yes	Yes
Constant	1.717***	-0.237	1.931***
	(0.439)	(0.674)	(0.454)
Observations	4,740	4,740	4,740

Robust standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

As expected, farm size (Size) decreases, and having a more diversified production system (DIVSPE) increases the probability of farmers participating in DTC channels, DTR channels and a combination of DTC and DTR channels. Most studies in the literature show that farms marketing through SFSC are smaller in size (Ahearn et al., 2018; Bruce & Som Castellano, 2016; Farmer & Betz, 2016; Filippini et al., 2018) and use diversified farming systems (Ahearn et al., 2018; Benedek

et al., 2018; Björklund et al., 2009). Being engaged in certified organic practices (ORG) increases the likelihood of marketing through DTC channels and through a combination of both DTC and DTR channels, but we find no evidence that this increases the probability of marketing through DTR channels. This finding is in line with studies showing that farmers who participate in SFSC are more likely to use organic farming practices (Aubert & Enjolras, 2016; Corsi et al., 2018; Navarrete, 2009). Using quality labels (LABEL) has a negative effect on the probability of adoption of DTC channels and participating in a combination of DTC and DTR channels, but we find no evidence that it has an effect on selling through DTR channels. This result is consistent with Corsi et al. (2018), who show that labels of origin may be better exploited in conventional channels.

4.4.2 Impact of SFSC strategies on synthetic pesticide use

Table 4.2 presents the estimates of the impact of the different SFSC involvement strategies on the application of synthetic pesticides (TFI) in vegetable production. Full models are available in Table A4.3 in the Appendix. Market gardeners who use only LFSC are the reference group. The estimated coefficients on the marketing options and the coefficients associated with the latent factors (λ) for synthetic pesticide use are the main findings of interest.

Table 4.2. Second stage estimate of synthetic pesticide use (TFI)

	OLS Model	Multinomial endogenous treatment effect model
	(1)	(2)
VARIABLES	Log(TFI)	Log(TFI)
Marketing options		
DTC channels	-0.362***	-0.723***
	(0.0252)	(0.0614)
DTR channels	0.0180	0.0285
	(0.0412)	(0.0818)
DTC + DTR channels	-0.263***	-0.493***
	(0.0280)	(0.0730)
Selection terms		
$\boldsymbol{\lambda_{DTC}}$		0.423***
		(0.067)
$\boldsymbol{\lambda_{DTR}}$		-0.005
		(0.077)
$\boldsymbol{\lambda_{DTC+DTR}}$		0.256***
		(0.084)
Constant	1.373***	1.602***
	(0.0752)	(0.0830)
Observations	4,740	4,740

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Results show that market gardeners who sell some of their vegetables through DTC channels use significantly fewer synthetic pesticides than those who produce only for LFSC. All other things being equal, switching from marketing vegetables only in LFSC to also marketing in DTC channels leads to a 72% reduction (± 6,1%) of synthetic pesticide use. We do not find evidence that farmers who sell some of their vegetables through DTR channels employ significantly fewer synthetic pesticides than those who sell only through LFSC. The only exception is when farmers combine both DTR and DTC sales, but the reduction effect is lesser than when the SFSC strategy includes only DTC sales. All other things being equal, switching from marketing vegetables only in LFSC to also selling them both in DTC and DTR channels leads to a 49.3% reduction of synthetic pesticide use (± 7,3%).

The coefficients of the latent factors (λ) capture the effects on synthetic pesticide use of unobserved characteristics linked to the choice of marketing strategies. Market gardeners engaged

in DTC channels and both DTC and DTR channels have positive significant selectivity correction terms, while these terms are not significant for those engaged in the SFSC strategy involving only DTR sales. This suggests that unobserved variables increasing the likelihood of adoption of SFSC strategies are associated with a higher use of synthetic pesticides, which means that if selection effects were overlooked, the predicted decline of synthetic pesticides would be underestimated.

4.4.3 Impact of SFSC strategies on crop yields

Table 4.3 reports the estimates of the impact of different SFSC strategies on vegetable production yields. Full models are available in Table A4.4 in the Appendix. Note that this model runs with fewer observations due to missing information on crop yields.

Table 4.3. Second stage estimate of crop yields

	OLS Model	Multinomial endogenous treatment effect model
	(1)	(2)
VARIABLES	Log(Yields)	Log(Yields)
Marketing options		
DTC	-0.102***	-0.125
	(0.0318)	(0.114)
DTR	0.0297	0.0589
	(0.0491)	(0.0789)
DTC + DTR	-0.0264	-0.0541
	(0.0348)	(0.122)
Selection terms		
λ_{DTC}		0.026
		(0.118)
λ_{DTR}		-0.032
		(0.045)
$\lambda_{DTC+\ DTR}$		0.031
		(0.126)
Constant	3.510***	3.527***
	(0.0947)	(0.133)
Observations	3,880	3,880

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

We did not find evidence of farmer participation in different SFSC channels having a negative effect on crop yields. In addition, the coefficients of the latent factors (λ) capturing the

effects on yields of unobserved characteristics linked to the choice of the different SFSC strategies are non-significant.

4.5 Discussion and conclusion

4.5.1 Main results

The major contribution of this article is to investigate the effect on synthetic pesticide use and crop yields of different strategies of farmer involvement in SFSC, depending on the presence or absence of an intermediary. We demonstrate that the effect of SFSC involvement on synthetic pesticide use varies depending on the SFSC types. Farmers who sell some of their vegetables through DTC channels employ significantly fewer synthetic pesticides than those who sell only through LFSC, while we find no evidence that farmers involved in DTR use significantly less synthetic pesticides. The only exception is when farmers combine both DTR and DTC sales, but the reduction effect is lesser than when the SFSC strategy includes only DTC sales. In addition, we did not find evidence that farmer participation in different SFSC strategies decreases crop yields. These results are consistent with Mount and Smither (2014) who show qualitatively that farmers engaged in DTR channels adopt farming practices that are close to those used in conventional markets.

The adoption of more sustainable farming practices is hampered by socio-economic, institutional and political constraints occurring at each level of the food chain (Boulestreau et al., 2021; Cowan & Gunby, 1996; Guichard et al., 2017; Magrini et al., 2016; Meynard et al., 2018; Togbé et al., 2012; Vanloqueren & Baret, 2008; Wilson & Tisdell, 2001). In particular, farming practices are strongly framed by the specifications of the marketing channels, which set prices and determine product types, assortments, and volumes as well as marketing standards. As in LFSC, farmers who sell part of their vegetables through DTR channels face marketing specifications that lock them into intensive farming systems. They have to efficiently provide a large and regular supply of uniform products while complying with stringent marketing standards (Zwart & Wertheim-Heck, 2021). For instance, farmers may apply synthetic pesticides in order to meet high cosmetic standards

imposed by retailer requirements and consumer preferences (Pimentel et al., 1993; Yue et al., 2009; Zakowski & Mace, 2022). In contrast, SFSC marketing requirements are less standardized, giving farmers room to implement more environmentally friendly farming practices (Bressoud, 2010; Lefèvre et al., 2020, 2020; Marechal & Spanu, 2010; Milford et al., 2021; Navarrete, 2009). For example, the adoption of pest- and disease-resistant crop varieties, which can significantly reduce reliance on synthetic pesticides, is faced with marketing constraints such as uncertainty regarding consumer preferences (Finger et al., 2022). Retailers and wholesalers prefer marketing well-established varieties due to the perceived low market opportunities of pest- and disease-resistant crop varieties (Finger et al., 2022; Zhang et al., 2019). In contrast, farmers engaged in DTC channels are more likely to adopt these varieties, because they are not constrained by retailer preferences/demands and can ensure stable marketing conditions by communicating their product characteristics with customers (Finger et al., 2022; Zhang et al., 2019).

The development of more environmentally friendly farming practices depends on farmers' capacity to be economically competitive (Crowder & Reganold, 2015; Reganold & Wachter, 2016; Rosa-Schleich et al., 2019; Sutherland et al., 2012). Both DTC and DTR channels can offer farmers economic benefits to outperform the disadvantages of yield losses that could be associated with the implementation of these alternative farming practices. A majority of consumers are willing to pay a premium for local food, and some studies show that this premium could be even higher in DTR channels because they are more conveniently located and offer complementary food products (Dunne et al., 2011; Richards et al., 2017). Farmers engaged in DTC channels prioritize more personal and meaningful connections with their consumers based on shared goals and values. This closer connection in DTC channels makes the tangible and intangible attributes of their products easier to recognize and allows farmers to command a price premium (Mount, 2012; Sundkvist et al., 2005; Verhaegen & Van Huylenbroeck, 2001). These closer interactions can even be considered as a substitute for organic certification, offering farmers a premium without the financial, administrative and time requirements of organic certification (Dabbert et al., 2014; Flaten et al., 2010; González-Azcárate et al., 2022; Higgins et al., 2008; Veldstra et al., 2014). There is no

particular SFSC strategy that works best for farmers and that could better help them to make their alternative farming financially viable (Chiaverina et al., 2023). However, the large size and primarily economic motivations of farmers involved in DTR channels limits their capacity to deliver the set of intangible qualities associated with local food and therefore their ability to capture a premium (Mount, 2012; Mount & Smither, 2014; Rosol & Barbosa, 2021).

Farmers' decision-making on pest management methods may also depend on decisions made on neighboring farms (Bakker et al., 2021; Läpple & Kelley, 2015; Stallman & James, 2015). The more environmentally friendly farming practices associated with DTC channels may also be explained by their social dimension; offering farmers the opportunity to connect with each other (Chiffoleau et al., 2016; Lamine et al., 2009; Marechal & Spanu, 2010; Zoll et al., 2021). By favoring the exchange of knowledge and the sharing of alternative values, DTC channels promote the implementation of new practices and solutions and keep farmers' motivation high (Chiffoleau et al., 2016; Lamine et al., 2009; Marechal & Spanu, 2010; Zoll et al., 2021). An example of this is the French network label "Welcome to the farm", which brings together more than 4,500 farmers involved in DTC channels and provides support and advice from Chamber of Agriculture advisors, as well as opportunities for experience sharing among farmers.

The latent factors confirm that the multinomial endogenous treatment effect model is appropriate for analyzing the effect of SFSC participation on farmers' synthetic pesticide use. Synthetic pesticide use of market gardeners engaged in DTC channels and in a combination of DTC and DTR channels is upwardly biased, meaning that there are unobserved factors pushing farmers to apply more synthetic pesticides. If selectivity effects were improperly overlooked, the predicted decline of synthetic pesticide use would have been underestimated. This result might be surprising, as we expected farmers involved in SFSC to have unobserved attributes, such as a stronger sense of environmental responsibility, driving them to reduce their application of synthetic pesticides. However, some studies find that farmers participating in SFSC do not necessarily display higher environmental awareness (Schoolman et al., 2021; Tregear, 2011), despite the fact that others find the opposite (Izumi et al., 2010; Leiper & Clarke-Sather, 2017). In addition, predicting the direction

of omitted variable bias is difficult, due to the presence of many omitted variables whose effect on the dependent variable may be not of the same sign (Basu, 2018). For example, the effect of SFSC participation is expected to be both biased downward, because synthetic pesticide use is estimated without taking account of farmers' motivation, and biased upward, due to omitting farmers' risk aversion in our regression model.

4.5.2 Limitations

Two issues that deserve discussion are those of the internal and external validity of the results. In terms of internal validity, information about marketing channels and our dependent variables (TFI and crop yields) are from two different databases from surveys carried out two years apart. Marketing channel information is from the 2020 agricultural census, and TFI and crop yields are from a national survey conducted in 2018 on the phytosanitary practices of representative market gardeners. Some market gardeners who indicated participation in SFSC in 2020 may not have been involved in 2018, and vice-versa, which could bias our results.

In terms of external validity, these results are obviously context-specific and should not be generalized. They are specific to French vegetable production anchored in socio-political contexts and farming systems. In addition, this study relies on data during one year, which provides a static view of the effect of SFSC participation on synthetic pesticide use. Although Schoolman (2019) shows that an increase in the strength of local food systems has been associated with a decrease in spending on synthetic pesticides in the US, the magnitude of this negative relationship has decreased over time. One explanation is that key local food stakeholders (e.g., producers, consumers) have placed greater priority over time on product freshness and nutrition and supporting small farmers rather than on low-input farming practices (Schoolman, 2019). More research is needed to find out whether the effect of SFSC participation on the use of synthetic pesticides has varied over time, in what direction and for what reasons.

4.5.3 Policy implications

Nevertheless, this study provides some clues indicating that public support of DTC channels can be a lever to overcome socio-economic constraints that inhibit the reduction of pesticide use and the development of alternative practices (Hu, 2020; Nagesh et al., 2023). The absence of a downward trend in the use of synthetic pesticides, despite substantial policy efforts made by the French government, is partly due to a lack of awareness of these socio-economic impediments by agricultural policies (Guichard et al., 2017; Guyomard et al., 2020; Hossard et al., 2017; Lamichhane et al., 2016). The performance of EU agri-environmental schemes has also been questioned, because they have failed to drive the necessary cultural changes to sustainably embed more environmentally sustainable farming practices within farming communities (Burton & Paragahawewa, 2011; de Snoo et al., 2013; Kleijn et al., 2006; Wilson et al., 2007).

In France, both financial measures and legal instruments exist to support farmers engaged in DTC channels and steer them more closely to greater sustainability. These measures come from a variety of levels, including European, national and local levels. The 2013 EU common agricultural policy reform made SFSC and local markets an explicit element of the EU rural development policy for 2014-2020 (European Parliament, 2016). Several measures have been designed to develop SFSC including investments in facilities for selling and processing agricultural products, setting up of producer groups and organizations, quality schemes, knowledge transfer, and training and advisory services. However, these measures have supported various types of SFSC and local markets, independently of their sustainability potential. The definition of SFSC and local markets at the French and European levels refers only to the number of intermediaries and geographical proximity, which is not a sufficient guarantee of sustainability (Kapała, 2022). Consequently, financial measures intended to support SFSC should include in their eligibility criteria or payment intensity, requirements on environmentally friendly production methods, as well as other sustainability criteria. In addition, programs supporting SFSC should be better evaluated in order to improve their effectiveness.

We show that uncertified organic market gardeners engaged in DTC channels use significantly fewer synthetic pesticides, which confirms that the closer interactions between farmers and consumers could be considered as a substitute for the organic certification label. We also find that organic certified farmers are more likely to be involved in DTC channels. These results demonstrate that promoting SFSC does not necessarily undermine programs aimed at promoting certified organic farming, as claimed by Chen et al. (2019). The EU Farm to Fork (F2F) strategy has set a target of having 25% of EU agricultural land under organic farming by 2030, from the current level of under 10%. To reach this ambitious goal, organic production policy in the EU provides small-scale and SFSC farmers better-targeted support (*Regulation (EU) 2018/848*). Our results highlight that organic farming policies should better encourage DTC rather than DTR channels, because they offer farmers more opportunities and autonomy to implement ecologically sound practices. Flaten et al. (2010) argue that reducing the number of farmers renouncing organic certification is a more efficient strategy to reach organic production goals than attracting newcomers. Further research is needed to understand the role of an organic third-party certification in SFSC. Some studies show that organic certification mainly benefits large farms with primarily economic motivations, which may lead to a deeper conventionalization of SFSC (González-Azcárate et al., 2022; Higgins et al., 2008).

In March 2023, the French government launched a €200 million sovereignty plan, with the goal of increasing fruit and vegetable production and making it more sustainable. In particular, this plan gives more financial aid to the Territorial Food Projects (PAT) established by France 2014 Law for the Future of Agriculture, Food and Forestry. These PATs have been mainly identified in the fruit and vegetable sectors and support territorialized food systems, SFSC and all forms of quality and environmentally friendly agriculture through a wide range of actions implemented at the local level (Darrot et al., 2019). Some studies have questioned the practical contribution of SFSC to food security, because farms engaged in SFSC are smaller in size and hardly able to scale-up and move beyond their niche level (Cerrada-Serra et al., 2018; Deppermann et al., 2018; Lutz and Schachinger, 2013; Sundkvist et al., 2005). Although we do not find evidence that SFSC participation decreases

crop yields, lack of evidence does not prove that the effect does not exist. In addition, high local food self-sufficiency is constrained by seasonality and can make food supply more vulnerable to production failures, such as climatic fluctuations or disease outbreaks (Sundkvist et al., 2005). However, food security is not only a matter of self-sufficiency and scale, but covers a wide range of challenges within the food system (Kirwan & Maye, 2013). Policies promoting DTC channels have a part to play in food security by favoring the adoption of more environmentally friendly practices in addition to fostering the resilience of the food system (Smith et al., 2016; Thilmany et al., 2021) and retaining domestic production (Kirwan & Maye, 2013).

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4.7 Appendix

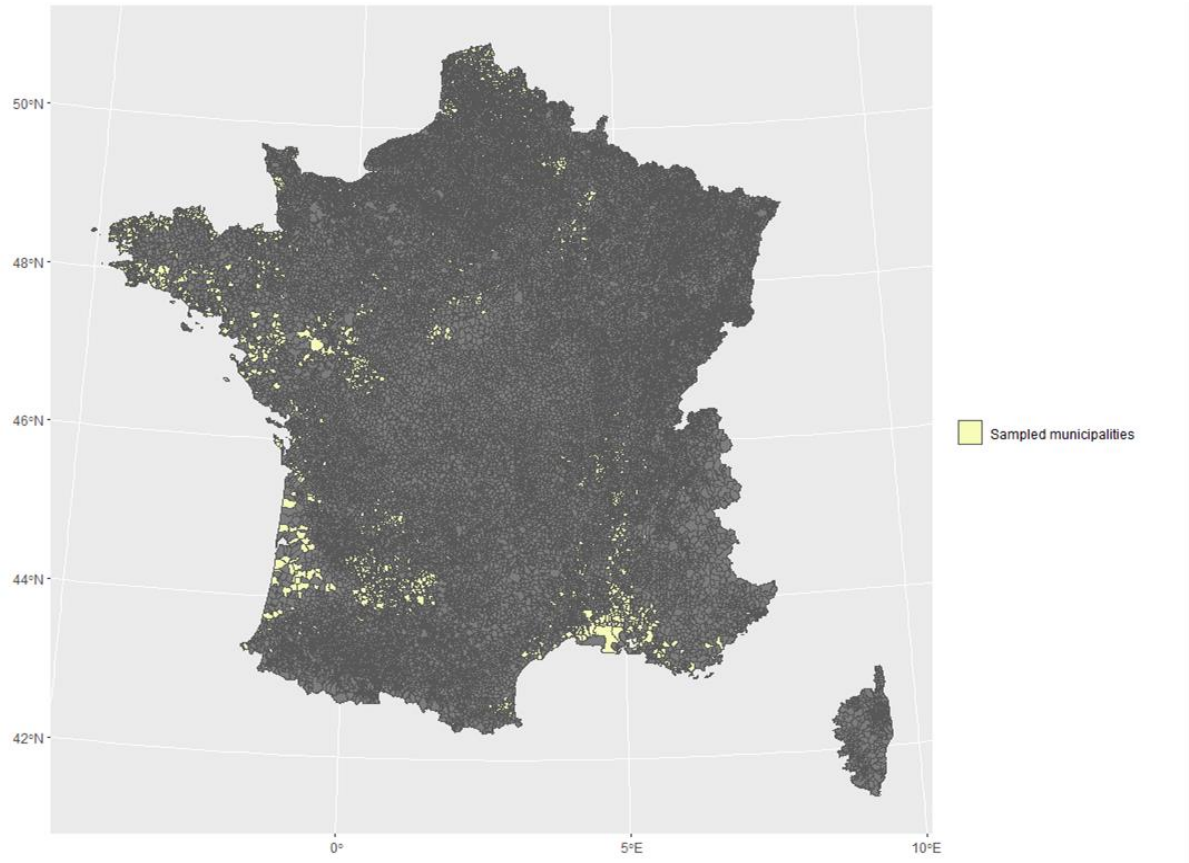

Figure A4.1. Sampled municipalities in market gardening (2018)

Table A4.1. Characteristics of market gardeners (N = 4740)

				LFSC			DMC			IMC			DMC + IMC		
Variable.	Unit.	Year	Source	Obs.	Means	Std Dev.	Obs.	Means	Std Dev.	Obs.	Means	Std Dev.	Obs.	Means	Std Dev.
SIZE*[16]	Utilized agricultural area (hectare)	2018	MA	2,576	88.9	101.3	1,152	30.5	47.6	233	51.7	90.4	779	32.1	56.1
DIVSPE*	Diversification of species (%)	2018	MA	2,576	0.26	0.24	1,152	0.51	0.26	233	0.40	0.24	779	0.52	0.24
DIVACT*	Dummy = 1 if principal operator has non-farming-activities	2020	AC	2,576	0.06	0.24	1,152	0.05	0.22	233	0.08	0.27	779	0.08	0.26
ORG*	Dummy = 1 if principal operator practices organic farming	2018	MA	2,576	0.10	0.30	1,152	0.32	0.47	233	0.21	0.40	779	0.47	0.49
LABEL*	Dummy = 1 if principal operator uses quality label	2018	MA	2,576	0.06	0.24	1,152	0.01	0.11	233	0.02	0.15	779	0.01	0.11
FEMALE*	Dummy = 1 if principal operator is a women	2020	AC	2,576	0.10	0.31	1,152	0.25	0.43	233	0.09	0.28	779	0.15	0.36
NOHIGHSCHOOL*	Dummy =1 if principal operator has less than a	2020	AC	2,576	0.72		1,152	0.60		233	0.69		779	0.50	

[16] The * symbol statistically significant differences in the means of the explanatory variables among the different marketing options.

	high school degree										
HIGHSCHOOL*	Dummy =1 if principal operator has a high school degree	2020	AC	2,576	0.18	1,152	0.20	233	0.16	779	0.27
BACHELOR*	Dummy =1 if principal operator has a bachelors' degree	2020	AC	2,576	0.05	1,152	0.10	233	0.07	779	0.10
MASTER*	Dummy =1 if principal operator has a master's degree	2020	AC	2,576	0.05	1,152	0.10	233	0.07	779	0.13
Age	Principal operator age	2020	AC	2,576	47.5	1,152	46.4	233	47.1	779	43.1
Pest	Dummy = 1 if presence of pest and disease problems on the parcel	2018	MA	2,576		1,152		233		779	
Distance*	Distance (km) from the nearest city of 20,000 or more			2,576	28.1	1,152	22.8	233	19.7	779	23.7

Table A4.2. Falsification test results in market gardening (parameter estimates from OLS regressions for farmers in the "Non-adoption" category)

	OLS Model
	(1)
Variables	Log(TFI)
Cabbage	-0.233***
	(0.0377)
Strawberries	-0.159**
	(0.0662)
Melons	-0.0752
	(0.0556)
Leeks	0.182***
	(0.0577)
Lettuces	-0.127**
	(0.0561)
Tomatoes	0.316***
	(0.0639)
Log(Size)	0.129***
	(0.0116)
ORG	-1.202***
	(0.0377)
DIVSPE	-0.112**
	(0.0523)
DIVACT	0.0489
	(0.0453)
LABEL	-0.0120
	(0.0469)
PEST	0.0704
	(0.0734)
FEMALE	0.00364
	(0.0369)
HIGHSCHOOL	-0.0474
	(0.0292)
BACHELOR	0.0355
	(0.0508)
MASTER	0.0832
	(0.0528)
AGE	0.000802
	(0.00110)
DISTANCE	0.000799
	(0.000926)
Region fixed effects	Yes
Constant	1.414***
	(0.115)

Observations	2,576

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table A4.3. Second stage estimate for pesticide use (TFI) in market gardening (Full model)

	OLS Model	Multinomial endogenous treatment effect model
	(1)	(2)
Variables	Log(TFI)	Log(TFI)
SFSC categories		
DMC	-0.362***	-0.723***
	(0.0252)	(0.0614)
IMC	0.0180	0.0285
	(0.0412)	(0.0818)
DMC + IMC	-0.263***	-0.493***
	(0.0280)	(0.0730)
Cabbage	-0.155***	-0.190***
	(0.0294)	(0.0289)
Strawberries	-0.194***	-0.190***
	(0.0463)	(0.0497)
Melons	-0.0537	-0.0295
	(0.0404)	(0.0415)
Leeks	0.0847**	0.0903**
	(0.0377)	(0.0397)
Lettuces	-0.247***	-0.272***
	(0.0376)	(0.0368)
Tomatoes	0.145***	0.145***
	(0.0421)	(0.0447)
Log(Size)	0.136***	0.102***
	(0.00726)	(0.00846)
ORG	-0.973***	-0.948***
	(0.0239)	(0.0275)
DIVSPE	-0.137***	0.0162
	(0.0383)	(0.0420)
DIVACT	-0.00412	0.0102
	(0.0351)	(0.0328)
LABEL	-0.0420	-0.0801*
	(0.0448)	(0.0427)
PEST	0.105**	0.111*
	(0.0500)	(0.0599)
FEMALE	-0.0648***	-0.0309
	(0.0251)	(0.0273)
HIGHSCHOOL	-0.0234	-0.0276
	(0.0226)	(0.0237)
BACHELOR	0.0714**	0.0860**
	(0.0344)	(0.0337)
MASTER	0.0376	0.0308
	(0.0346)	(0.0341)

AGE	8.29e-05	-0.000476
	(0.000859)	(0.000919)
Region fixed effects	Yes	Yes
Constant	1.373***	1.602***
	(0.0752)	(0.0830)
Observations	4,740	4,740

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table A4.4. Second stage estimate for Yields in market gardening (full model)

	OLS Model	Multinomial endogenous treatment effect model
	(1)	(2)
Variables	Log(Yields)	Log(Yields)
SFSC categories		
DMC	-0.102***	-0.125
	(0.0318)	(0.114)
IMC	0.0297	0.0589
	(0.0491)	(0.0789)
DMC + IMC	-0.0264	-0.0541
	(0.0348)	(0.122)
Cabbage	-0.970***	-0.972***
	(0.0366)	(0.0367)
Strawberries	-1.258***	-1.257***
	(0.0584)	(0.0700)
Melons	-0.708***	-0.706***
	(0.0502)	(0.0529)
Leeks	-0.356***	-0.357***
	(0.0471)	(0.0454)
Lettuces	-0.700***	-0.703***
	(0.0471)	(0.0551)
Tomatoes	0.530***	0.529***
	(0.0536)	(0.0637)
Log(Size)	0.0275***	0.0250
	(0.00922)	(0.0158)
ORG	-0.262***	-0.259***
	(0.0301)	(0.0368)
DIVSPE	0.198***	0.209***
	(0.0474)	(0.0705)
DIVACT	-0.0346	-0.0335
	(0.0415)	(0.0441)
LABEL	-0.00630	-0.00852
	(0.0502)	(0.0450)
PEST	-0.474***	-0.475***
	(0.0612)	(0.0813)
FEMALE	-0.0781**	-0.0769**
	(0.0325)	(0.0345)
HIGHSCHOOL	-0.0155	-0.0150
	(0.0277)	(0.0278)
BACHELOR	0.0688	0.0703
	(0.0429)	(0.0430)
MASTER	-0.00601	-0.00523
	(0.0433)	(0.0519)

AGE	0.000803	0.000739
	(0.00106)	(0.00111)
Region fixed effects	Yes	Yes
Constant	3.510***	3.527***
	(0.0947)	(0.133)
Observations	3,880	3,880

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1