Evaluating the impact of direct sales on farms' sustainability: a comparison of metropolitan and overseas France

Camille Luis, Magali Aubert

Evaluating the impact of direct sales on farms' sustainability: A comparison of Metropolitan and overseas France

Luis Camille[1], Aubert Magali[2]

Abstract
In the face of growing demand for local products, farmers are developing direct sales. Our research examines the impact of this strategy on farms' sustainability. Focusing on the market gardening sector, we compare metropolitan France and its overseas departments: Martinique, Guadeloupe and Reunion. These insular economies must meet national and European requirements for healthy and local production while complying with specific organizational and geographic conditions. If direct selling is considered an innovation, we first identify the factors, such as characteristics of farmers and their farm, determining its adoption. While establishing the link between such an innovation and performance, we study the impact of direct sales on farms' sustainability, inspired by the IDEA method. We use representative farm data from 2010 and 2016 and perform a propensity score matching coupled with a difference-in-difference analysis. While the impact of direct sales on sustainability is effective in metropolitan France, more nuanced results are observed in insular economies. Whatever the location, direct sales provide a response to consumers' expectations in terms of product diversification. While direct sales are initially associated with product processing and tourism, these activities are gradually abandoned, in particular because of the skills necessary to their realization. In metropolitan France, direct selling modifies the relationship with certifications by developing organic production to the detriment of other types of certification. It is also accompanied by output and employment growth. Our results question the role that the environment in which farmers evolve plays in the sustainability dynamics of farms in island economies.

Keywords direct sales; IDEA method; island economies; innovation; propensity score matching; difference-in-differences

Author Declarations This version of the article has been accepted for publication, after peer review but is not the Version of Record and does not reflect post-acceptance improvements, or any corrections. The Version of Record is available online at: http://dx.doi.org/10.1007/s41130-023-00195-5. Use of this Accepted Version is subject to the publisher's Accepted Manuscript terms of use https://www.springernature.com/gp/open-research/policies/acceptedmanuscript-terms.

Funding This action is led by the Ministries for Agriculture and Food Sovereignty, for an Ecological Transition and Territorial Cohesion, for Health and Prevention, and of Higher Education and Research, with the financial support of the French Office for Biodiversity, as part of the call for research projects "Global approaches to limit the use of phytopharmaceutical products: Coupling preventive and curative measures within the supply chain, from farmers to consumers", with the fees for diffuse pollution coming from the Ecophyto II+ plan.

Data availability Access to some confidential data, on which this work is based, was made possible within a secure environment provided by CASD – Centre d'accès sécurisé aux données (Ref. 10.34724/CASD)

Authors' contribution All authors contributed to the study conception and design. AM identified the theoretical approach and the methodology conducted. Data analysis was performed by LC. All authors wrote, read and approved the final manuscript.

Luis, C., Aubert, M. Evaluating the impact of direct sales on farms' sustainability: a comparison of metropolitan and overseas France. *Rev Agric Food Environ Stud* (2023). https://doi.org/10.1007/s41130-023-00195-5

[1] Corresponding author : CIRAD UPR Hortsys, F-97285 Le Lamentin, Martinique, France ; UMI SOURCE, EDEM Univ Paris Saclay, Paris, France. camille.luis@cirad.fr
ORCID : 0000-0001-5121-3442

[2] MoISA, Univ Montpellier, CIRAD, CIHEAM-IAMM, INRAE, Institut Agro, IRD, Montpellier, France. magali.aubert@inrae.fr
ORCID : 0000-0002-3905-4298

1. Introduction

In 2010, 18% of farmers in metropolitan France sold all or part of their production in short food supply chains (Agreste, 2011a). Short food supply chains create either a direct link between producers and consumers without intermediary, or an indirect link through an intermediary (Berthelot, 2003). This marketing method is favored in the overseas departments, as it concerns 71% of the farmers in Martinique, 60% in Reunion and 57% in Guadeloupe (Agreste, 2011b, 2011c, 2011d). This alternative makes it possible to respond in part to the constantly changing expectations of consumers for healthy and local production, thanks in particular to a physical place of sale and meeting point between the consumer and the producer and a greater transparency and sense of community (Jarzębowski et al., 2020).

Initially considered as a norm rooted in the history of agriculture (Chiffoleau & Prévost, 2013; Vaillant et al., 2017), direct sales – which systematically linked producers and consumers – gave way to longer marketing channels after the Second World War. This change was accompanied, among other things, by the development of the agri-food industry and large-scale distribution, the modernization of agriculture, and a greater organization of the supply chains (Le Clanche & Pluvinage, 2011).

The resurgence of short food supply chains, and more particularly of direct sales, since the beginning of the 2000s is partly linked to health crises and food safety crisis (mad cow crisis, horse meat lasagna scandal, etc.) which have led consumers to express their need for transparency, trust and proximity with producers (Chiffoleau & Prévost, 2013). At the same time, growing environmental awareness and greater concern for public health are driving the emergence of new marketing methods (Capt & Wavresky, 2014). Public actors also contribute to the development of short food supply chains (Aubert, 2016). For example, the implementation of the Barnier plan in 2009 by the Ministry of Agriculture *"encourages the development of short food supply chains by underlining the territorial, economic and consumption-related stakes associated with this marketing method*" (Laillet, 2013). More recently, the Ministry of Agriculture, in partnership with the Chambers of Agriculture, launched the "Fresh and local"[3] platform in January 2021, enabling consumers to find producers and direct sales outlets throughout France.

As one of the main actors in the chain, producers are of particular interest. Meeting the dual challenge of local and healthy production represents an economic and agronomic opportunity: economic in that it allows the producer to capture a larger share of the added value, and agronomic insofar as it meets the objective of reducing the use of phytosanitary products. However, while marketing via short food supply chains appears to be an opportunity for producers, the impact on their farms must be quantified.

Marketing via short food supply chains can be seen as an innovation, as it represents an alternative to the dominant agro-industrial supply chains and renews the producer-consumer relationship (Aubry & Chiffoleau, 2009; Chiffoleau & Prévost, 2013; Vaillant et al., 2017). It is interesting to study its effect on farm performances, which can be measured in terms of sustainability (Elkington, 1998; Jarzębowski et al., 2020). Using the conceptual framework of the method of sustainability indicators for farms (IDEA method[4]), the objective of our study is to analyze the impact of direct sales on the economic, socio-territorial and agro-ecological sustainability of farms in metropolitan France and in the overseas departments. More precisely, our study focuses on market gardening crops, including vegetables and root crops, which are characterized by their seasonality, high perishability and sensitivity to pests and diseases. These crops are particularly interesting to study as they represent one of the main types of production marketed in short food supply chains in France (Aubert & Enjolras, 2016). One of the particularities of island economies is their small geographical scope and their strong propensity to favor short supply chains. As the involvement of more than one intermediary in the marketing chain is rarer than in metropolitan France in the market gardening sector (Agreste, 2022), we dissociate direct sales with no intermediary (on-farm sales, farmers' markets) from the intermediated sales with at least one intermediary (sales to catering, sales to wholesalers) in order to assess the impact of direct sales on farms' sustainability.

While the literature underlines the existence of a link between adopting an innovation and performance (Debbahi & Kerzabi, 2015; Davies & Buisine, 2017), it also highlights the active role of the entrepreneur in the decision-making process (Schumpeter, 1939). The individual characteristics of the entrepreneur and their firm condition not only the propensity to adopt but also the observed trajectory. We consider the importance of these factors to control for any interpretation bias and thus to measure the impact of adopting an innovation on farm performance.

[3] https://www.fraisetlocal.fr/
[4] https://methode-idea.org/2

Insofar as the geographical location is a key factor in adopting an innovation (Feder et al., 1985; Ormrod, 1990), we distinguish between farms located in metropolitan France and those located in Martinique, Guadeloupe and Reunion.

From an empirical point of view, we use data from the exhaustive 2010 agricultural census and from the 2016 structural survey, which is representative of French farms. These data provide information on the structural characteristics of the farms, the individual characteristics of the farmers and also facilitate an assessment on the three pillars of sustainability. In addition, the data allow to capture the farm trajectories over the period 2010-2016. From a methodological point of view, we combine propensity score matching and difference-in-differences methods. The latter make it possible to measure the impact of a treatment (here direct sales) by controlling for the individual and structural parameters of the farmers and their farms.

In the first part of this article, we describe the context of the study and more particularly the particularities of island economies compared to metropolitan France. We develop the theoretical framework of our analysis in the second part before presenting the methodology adopted in the third part. The fourth part presents the results obtained and the last part concludes.

2. Context

The islands of Martinique, Guadeloupe and Reunion are all overseas French departments and outermost regions from the point of view of the European Union. They are subject to the same laws as metropolitan France, but benefit from special provisions. Adaptations to the laws and regulations are possible, as provided for in Article 73 of the Constitution. Thanks to their status of outermost regions, they benefit – in addition to national aid – from the European Union's program of options specifically relating to remoteness and insularity (POSEI), the main objective of which is to improve the economic and technical competitiveness of the agricultural sectors through aid to local agricultural production and to input importation (Toute l'europe, 2019).

However, the particularities of island departments and the challenges they may face are not sufficiently considered. These economies are considered fragile because of a higher rate of unemployment and precariousness than in metropolitan France. They are dependent on financial transfers from the European Union; transfers that structure the economic sectors benefiting from them, including the so-called "*export*" crops (mainly bananas and sugarcane) (Berthelot, 2003). Alongside these export crops, fruit and vegetable production represents more than a quarter of the agricultural production of these three islands (François et al., 2013; DAAF Réunion, 2019). However, vegetable and root crops are significantly declining with a 15% decrease in the area under vegetables and roots between 2000 and 2010 in the overseas (Agreste, 2011b) and a strong disappearance of small farmers with for instance more than 50% of vegetable farms disappearing in Martinique on the same period (Agreste, 2011c). The situation is similar in metropolitan France, with a decline of around 20% in the number of farms specialized in vegetable crops between 2000 and 2010 (Agreste, 2011a).

The vegetable and root crops production suffer from the lack of organization of the sectors and of suitable regional, national and European aid (Berthelot, 2003; Delcombel, 2005). Several producer organizations are present in these territories but do not manage to structure the whole sector or to stimulate a collective dynamic. Indeed, several obstacles to collective action such as producers' "*individualism*" or management difficulties from organizations make this structuring difficult (Delcombel, 2005). Similarly, the interprofessional groupings composed of farmers' organizations, processing industries and retailers from the sector are not able to structure the entire production. At the same time, direct sales on fair markets or at the roadside as well as informal sales are highly developed. This reflects the lack of formal organization of the sectors and reveals the numerous constraints faced by farmers when it comes to marketing through the demanding and competitive long supply chains (Delcombel, 2005; François et al., 2013).

However, it remains difficult for producers to promote their production through direct sales. First and foremost, producers mention low attendance at farmers' markets due to a lack of communication on local product marketing initiatives. They also highlight the fierce competition on these markets. By offering a greater variety of products to customers, retailers are important competitors for farmers even though the traceability of products is often not clearly established. However, this traceability is necessary to provide consumers with a guarantee of quality, underlining the need for communication and identification for direct-selling producers (ODEADOM, 2014).

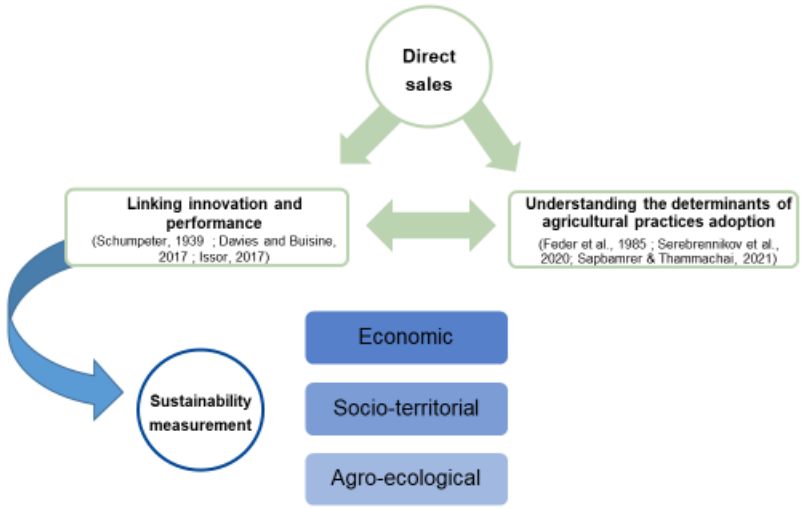
Insofar as the overseas departments are territories with a surface area smaller than most of metropolitan departments, the involvement of more than one intermediary in the marketing chain is rarer than in metropolitan France in the market gardening sector (Agreste, 2022). It is therefore appropriate to question the real distinction

between indirect short supply chains and long supply chains. The presence of one or more intermediaries necessarily implies a contractualization of exchanges, whether with producers' organizations or resellers (Freguin et al., 2020). It is therefore necessary to dissociate direct sales from contractual sales. Consequently, we differentiate direct sales from indirect sales implying one or more intermediaries in our study.
Beyond the organizational forms observed within these economies, we note not only a constantly evolving pest pressure but also the frequent occurrence of natural disasters (floods, hurricanes, volcanic activity, etc.) (Ludovic et al., 2008; Blazy et al., 2011). These factors make these three territories vulnerable and do not facilitate the organization and regularity of supply for producers, who remain dependent on climatic and agronomic conditions. This dependence makes it more difficult to adopt environmentally-friendly practices, particularly the conversion to organic farming.

In this context, it is appropriate to question both the determinants of direct sales marketing and the impact of direct sales on farms' sustainability in metropolitan France and its overseas departments.

3. Theoretical framework

In the literature, short food supply chains are seen as innovative practices contributing to sustainable development (Aubry & Chiffoleau, 2009; Chiffoleau & Prévost, 2013; Vaillant et al., 2017). The adoption of these innovative practices is based on the farmers' individual characteristics and the structural characteristics of their farms (Aubert, 2017). To identify these characteristics, we rely on the literature related to the determinants of adoption of agricultural practices (Feder et al., 1985; Serebrennikov et al., 2020; Sapbamrer & Thammachai, 2021) and more particularly of direct selling (Capt & Wavresky, 2014; Aubert, 2016). This allows to obtain a fine measurement of the impact of the innovation on farms' sustainability insofar as we control for all the factors conditioning the adoption of this innovation (Aubert & Enjolras, 2014; Malak-Rawlikowska et al., 2019; Jarzębowski et al., 2020). In order to justify the choice of sustainability indicators, we rely on the conceptual framework of the IDEA method, which integrates an agro-ecological, socio-territorial and economic scale to assess the strengths and weaknesses of the production system (Zahm et al., 2019). Figure 1 illustrates the complementarity of the approaches used in this study.



Source: Own representation

Fig. 1 Articulation of the theoretical approaches used

3.1. Linking innovation and performance

The work of Schumpeter (1939), a pioneer in the field of innovation, highlights the different forms of innovation in order to illustrate their variety. Among the forms of innovation identified, we find new consumer objects, new methods of production and transport, new markets and new types of industrial organization. The OECD (2010) completes this definition and speaks of "*implementation of a product, whether a good or a service, of a new or significantly improved process, of a new marketing method or of a new organizational method in the practices of the company, the organization of the workplace or external relations*".

It is through the implementation of new methods modifying the marketing of products that farmers innovate and try to break away from the classic farming systems and the productivist agricultural model (Le Clanche &

Pluvinage, 2011; Davies & Buisine, 2017). This agricultural model certainly has its limits and seems out of step with the ambition of agro-ecological transition and the multiple objectives defined by governments (Pouch, 2020). Although direct marketing channels are not new and were pioneers in the history of agriculture, new distribution channels are nevertheless emerging while others are renewing themselves and innovating by considering the stakes of sustainable development. This is notably the case with basket sales and consumer deliveries, which introduce a new form of relationship while maintaining a certain proximity between consumers and producers. Short food supply chains and, more precisely, direct sales initiatives are therefore new methods of marketing, representing a form of organizational and social innovation (Chiffoleau & Prévost, 2013; Vaillant et al., 2017).

Schumpeter (1939) was one of the first to place innovation at the heart of economic growth. Likewise, Porter (1980) emphasizes the fundamental role of innovation for companies, as it conditions their ability to maintain sustainable competitive advantages in evolving markets. The literature also agrees that innovation is a key factor in the competitiveness and performance of companies (Debbahi & Kerzabi, 2015; Davies & Buisine, 2017; Issor, 2017).The notion of performance is nevertheless difficult to define because it has a multidimensional character that is not limited solely to the financial dimension (Issor, 2017). Baret (2006) speaks of global performance as an "*aggregation of economic, social and environmental performance*". This refers to the notion of sustainability and underlines the need to consider the behavior of the company. Elkington (1998) introduces the notion of triple bottom line, which applies the notion of sustainable development to the company and to the evaluation of its performance by focusing on the three economic, social and environmental pillars. More recently, many sustainability assessment approaches were developed in order to account for the multifunctionality in agriculture. This is notably the case for the IDEA method which aims to evaluate the farm systems thanks to a set of indicators, either quantitative or qualitative (Briquel et al., 2001).

3.2. Understanding the determinants of agricultural practices adoption

To identify the set of characteristics intrinsic to the farmer and their farm that may influence the decision to adopt a new agricultural practice, we call on the literature related to technology adoption. More particularly, we focus on the agricultural sector in order to understand why an innovation, and more specifically a new marketing method, is adopted. Numerous literature reviews highlight the plurality of individual and structural factors influencing the adoption of an agricultural innovation (Feder et al., 1985; Serebrennikov et al., 2020; Sapbamrer & Thammachai, 2021). The combination of farmers' and farms' characteristics and their proper articulation would allow a farmer to diversify and change their practices, especially in terms of marketing methods (Capt & Wavresky, 2014; Aubert, 2016).

3.2.1. Farmers' characteristics:

The characteristics of the farmers and the assets present on the farm are universally considered in the literature as decisive in implementing an agricultural innovation (Aubert, 2017). Among the characteristics cited in the literature, the level of education would appear to be one of the key factors. A higher level of education translates into a greater ability to assess benefits and risks, to obtain information, and thus to innovate (Deressa et al., 2009; Capt & Wavresky, 2014; Azam & Banumathi, 2015). The best-educated farmers tend to be the first to adopt modern innovations.

In addition to the farmer's level of education, the time they devote to the farm is essential in their decision to adopt. Direct sales are associated with an additional workload that falls, either totally or partially, on the farm manager who must take care of all the stages not only of the production process but also of the marketing (Kirsch, 2021). The fact that the producer does not devote all their time to their farm can therefore be an obstacle to the adoption of new practices.

3.2.2. Farms' characteristics:

Farm-specific characteristics also play an important role in the decision to adopt an innovation. The main resource available on a farm is its utilized agricultural area (UAA). A larger farm can allow for diversification and innovation (Fernandez-Cornejo et al., 1994; McNally, 2001). In particular, larger farms tend to have more capital available and greater wealth (Feder et al., 1985; Ilbery, 1991) in comparison to smaller farms which may face credit constraints (Caswell et al., 2001). Farm size is thus highlighted in the literature as playing a key role in the adoption of an innovation.

3.2.3. Consideration of the geographical location

Beyond the individual and structural characteristics available on a farm, greater attention must be paid to the role of the geographical location in which farmers operate, as it conditions the trajectories of their farm (Feder et al., 1985). Indeed, the geographical location, the insular character, the climatic conditions, the pest pressure, etc. are all factors that should not be neglected when studying and comparing the impact of direct sales on farms' sustainability in different regions (Feder et al., 1985; Fernandez-Cornejo et al., 1994; Mwiathi, 2008).

In the literature, different measures are used to study the influence of the geographical location: the proximity of urban areas (Koesling et al., 2008), a soil aridity index (Genius et al., 2006) and the location of the farm in an irrigated area (Rodríguez-Entrena & Arriaza, 2013). Within the framework of our study, we consider the region in which the farm is located in metropolitan France (Malá & Malý, 2013; Métouolé Méda et al., 2018) and we also differentiate between Martinique, Guadeloupe and Reunion in order to capture the heterogeneity of these three islands.

3.3. Measurement of sustainability

To assess farms' sustainability following a change in the marketing method, we rely on the conceptual framework of the IDEA method. This method was developed for an education aim and seeks to help farmers to progress and reach sustainability goals. It permits to assess the farm systems through various quantitative and qualitative indicators (Briquel et al., 2001). Hence, this method allows us to consider the particularities of production and to justify our choice of indicators selected to measure sustainability. From a theoretical point of view, the choice of indicators is firstly based on the five properties of a sustainable agricultural system identified in the literature: productive and reproductive capacity of goods and services, territorial anchorage, autonomy, robustness and global responsibility. This choice is also based on 12 objectives of a sustainable farm that consider the multifunctionality of agriculture, i.e. the diversity of its economic, social and environmental utilities (Laurent, 2001). This method gathers 53 indicators divided into 13 components that serve to evaluate sustainability according to the three pillars of sustainable development: economic, socio-territorial and agro-ecological. As we cannot compute the 53 indicators with the data available, we use the theoretical framework of the IDEA method as a benchmark to create our own indicators. We develop a list of indicators that allows us to evaluate the sustainability of farms at a more aggregated level, with each pillar represented by at least 2 indicators.

The IDEA indicators concerning the economic sustainability are built on 4 domains: the viability, efficiency, independence and transferability of the farm. To consider these 4 domains, the IDEA method relies on several indicators such as the available income per worker, the economic specialization rate, the financial autonomy or the amount of operating expenses. As these indicators are not directly available in our data, we approximate them with other indicators that reflect these same domains.

First, the literature agrees that direct sales allow producers to be remunerated more fairly because of the absence of intermediaries (Aubert & Enjolras, 2014; Malak-Rawlikowska et al., 2019). We assume that this marketing mode results in higher output, which we measure by standard gross production[5] **(H1).**

H1: Direct sales marketing is associated with a higher output

Moreover, the UAA is considered as one of the main resources of the farm. It refers to different aspects such as the presence of capital, access to credit, economies of scale and managerial capacities (Feder et al., 1985; Fernandez-Cornejo et al., 1994; Mwiathi, 2008) which are all aspects related to the viability, efficiency and independence of the farm. As direct sales lie on diversification of the distribution channels (Ilbery, 1991; Malak-Rawlikowska et al., 2019), we test the hypothesis that they lead to bigger farms as the farmer tends to increase his output and diversifies even more his activity (Alonso Ugaglia et al., 2020) **(H2).**

H2: Direct sales marketing is associated with a bigger farm size

This marketing method also encourages a dynamic of innovation and diversification on the farms as well as more autonomy in setting prices (Alonso Ugaglia et al., 2020). This is particularly the case with the establishment of

[5] Standard gross production describes a farm's production potential and allows us to classify farms according to their economic size.

processing activities for agricultural products following the change in the marketing method, which allows farmers to integrate within their farms the processing of their production **(H3).**

H3: Direct sales marketing is associated with more processing activities

Finally, it is also interesting to consider the share of para-agricultural diversification activities like contract work, crafts or forestry in the total turnover of the farm **(H4).** These activities support the farm's profitability and are linked to less economic uncertainties (Jarzębowski et al., 2020). Such indicator allows to measure the contribution of income not linked to the main activity to the independence of the farm.

H4: Direct sales marketing is associated with a greater share of para-agricultural diversification activities

To assess socio-territorial sustainability through the IDEA method, 4 domains are highlighted: ethics and human development, local development and circular economy, employment and quality at work, food sufficiency and the quality of the products and land. We first include a range of indicators related to employment. Following a change in the marketing mode, the farmer has new tasks, not linked to the agricultural activity, and farm management becomes more complex (Alonso Ugaglia et al., 2020; Jarzębowski et al., 2020). We therefore assume that this marketing mode is often associated with a larger workforce **(H5).**

H5: Direct sales marketing is associated with a greater workforce

This additional workforce being mainly local, it participates to the local social development (Alonso Ugaglia et al., 2020). In terms of intensity and quality of work, it is interesting to study the proportion of permanent employees **(H6)** and of external employees (company personnel or groups of employers for example) **(H7)** in order to measure the stability of employment and the mutualization of agricultural work.

H6: Direct sales marketing is associated with a greater proportion of permanent employees

H7: Direct sales marketing is associated with a lower proportion of external employees

Direct sales are also associated with more pluriactivity and/or diversification (Alonso Ugaglia et al., 2020). This helps reinforce social links, in particular through the establishment of para-agricultural activities linked to tourism (leisure, catering, accommodation) **(H8).**

H8: Direct sales marketing is associated with the implementation of touristic activities

Direct sales would thus contribute to a territorialized social cohesion through the employment and the relations of proximity that it generates (Jarzębowski et al., 2020). As the IDEA method considers new societal issues, in particular relating to food, we consider the certification of food production through commitment to an official quality sign **(H9)** or organic agriculture certification **(H10).**

H9: Direct sales marketing is associated with a greater certification with official quality signs

H10: Direct sales marketing is associated with a greater certification in organic agriculture

In the IDEA method, the agro-ecological dimension is captured by 20 indicators reflected in 5 domains: functional diversity, sobriety in the use of resources, reduction of impacts on human health and ecosystems, ensuring favorable conditions for production, looping of material and energy flows. As some of these domains are already covered by the previous indicators related to certification, we mainly focus on the domain related to functional diversity. Insofar as direct sales are often associated with greater crop diversification with the aim of offering consumers a greater variety of products (ODEADOM, 2014), we consider the diversity of cultivated species, whether this is intra-crop diversification (market gardening crops) **(H11)** or inter-crop diversification (livestock, fruits, etc.) **(H12).** This diversification is presented as a lever for action to promote a more sustainable agriculture (Meynard et al., 2013).

H11: Direct sales marketing is associated with greater intra-crop diversification

H12: Direct sales marketing is associated with greater inter-crop diversification

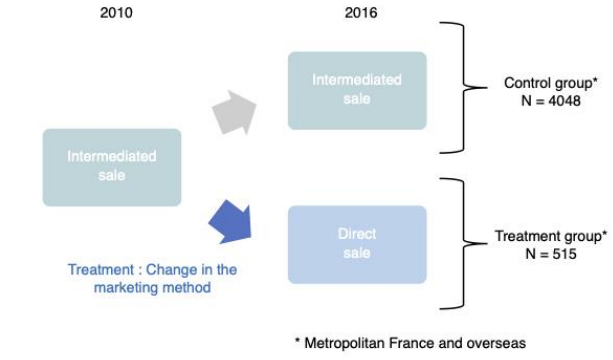
In Table 1, we present all the selected sustainability indicators and determinants of innovation adoption.

4. Data

For our study, we use data from the 2010 agricultural census and the 2016 farm structure survey. The 2010 census concerns 518,925 farms and was carried out in metropolitan France and in the overseas departments (Reunion, Guadeloupe, Martinique, French Guiana). The main purpose of this census was to determine the structure of farms and measure their evolution in terms of production and agricultural population. The 2016 structure survey allows to update the exhaustive data of 2010 with a representative sample of 62,377 farms surveyed in metropolitan and overseas France.

The farms surveyed within the framework of the agricultural census and the structure survey are uniquely identified. This allows for a dynamic analysis over the entire period. All farms with at least one hectare of UAA or at least 0.2 hectares for specialized crops or certain types of animal are accounted for. This definition thus includes both farmers who are primary farmers and farmers whose agricultural activity is secondary. Since French Guiana is a continental territory, we concentrate our analysis only on Martinique, Guadeloupe and Reunion, which are comparable due to their status of island departments.

Our study focuses on market gardening production, which is one of the main types of production marketed in short food supply chains (Aubert & Enjolras, 2016). This sector is of particular interest as it concerns high-value crops, which are highly diverse, perishable and labor and knowledge intensive (FAO, 2021). We therefore consider farms specialized in market gardening in 2010, i.e. those where market gardening (including vegetables and root crops) accounts for more than 2/3 of the agricultural income. We assume that they maintain at least one market gardening activity throughout the period. We notice that in our sample a larger share of farms is specialized in market gardening in the overseas with respectively 37%, 56% and 50% of market gardening specialization in Martinique, Guadeloupe and Reunion against 7% of specialization in metropolitan France. To conduct a medium-term analysis, we keep the farms identified over the two years. Among these farms, we select those marketing in long supply chains or indirect sales in 2010. This selection allows us to construct the control group composed of farms marketing in long supply chains or indirect sales in 2010 and 2016 and the treatment group composed of farms which changed their marketing strategy in 2016 (Figure 2). The identification of our final sample is shown in Figure 3.



Source: Own representation

Fig. 2 Construction of control and treatment groups

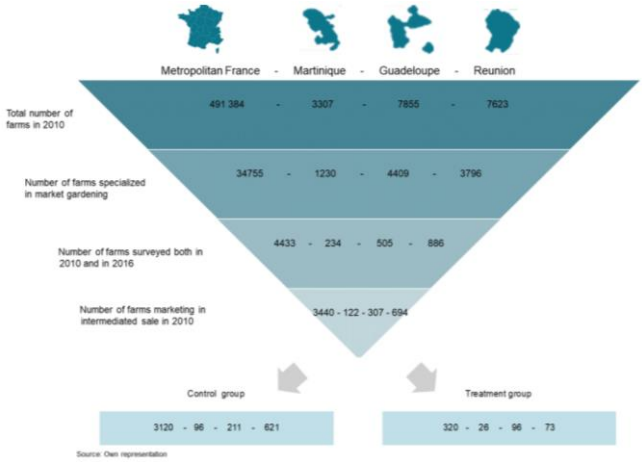


Fig. 3 Sampling method

Table 1 Description of variables

Variable	Description	Unit
	Marketing mode	
Direct sale	Marketing in direct sale (no intermediary), all or part of the production	1 if yes, 0 otherwise
Indirect sale	Marketing in indirect sale (one intermediary) or in long supply chain (more than one intermediary), all or part of the production	1 if yes, 0 otherwise
	Farmers' and farms' characteristics	
Education	Agricultural, general or technical education (initial or continuous) of the farmer	1: No diploma 2: Secondary education 3: Higher education
Main activity	The farmer spends more than 3/4 of his time on the farm	1 if yes, 0 otherwise
UAA	Utilized agricultural area (UAA) in hectares	Ha
	Geographical location	
Region	Location of the farm in metropolitan France or in the overseas	1: Metropolitan France 2: Guadeloupe 3: Martinique 4: Reunion
Metropolitan region	Region of the farm in metropolitan France	Region code

	Sustainability indicators	
Economic sustainability		
H1: SGP	Standard gross production (SGP): value of potential production per hectare	€
H2: UAA	Utilized agricultural area (UAA) in hectares	Ha
H3: Processing	Diversification of the activity by processing milk, olive oil or other agricultural products	1 if yes, 0 otherwise
H4: Turnover from diversification	Share of para-agricultural diversification activities in the total turnover of the farm > 10% (contract work, crafts, aquaculture, forestry, renewable energy production, tourism, etc.)	1 if yes, 0 otherwise
Socio-territorial sustainability		
H5: Employment	Amount of work done on the farm in annual work units	Annual work unit
H6: Permanent employment	Share of permanent employees in the total number of employees	%
H7: External employment	Quantity of work provided on the farm in annual work units by company personnel (ETA, CUMA) or employed by a group of employers or other service providers	Annual work unit
H8: Tourism	Diversification into accommodation, catering and/or leisure activities	1 if yes, 0 otherwise
H9: Products' quality	Products under quality sign: Protected Geographical Indication, other indications of source (AOC/AOP), Label Rouge etc.	1 if yes, 0 otherwise
H10: Organic certification	Production of crops certified or in the process of conversion to organic agriculture	1 if yes, 0 otherwise
Agro-ecological sustainability		
H11: Intra crop diversification	Number of market gardening productions	Counter
H12: Inter crop diversification	Number of other productions (cereals, livestock, etc.)	Counter

Source: The authors.

5. Methodology

Once we identified the key factors in the adoption of an innovation, we can correct any bias related to this prerequisite. We thus relax the hypothesis that farmers marketing through direct sales (the treatment group: TG) have similar characteristics to those who do not (the control group: CG). Unlike randomized experiments, natural experiments do not allow a direct comparison of both groups because observations exposed to a treatment are generally different from unexposed observations (Rosenbaum & Rubin, 1983).

The propensity score matching method is often used to solve this problem of sample selection bias. It allows not only the comparison of the TG and the CG but also to obtain a result close to that of a randomized study. To provide consistent estimates of the treatment effect, Rosenbaum and Rubin (1983) propose the propensity score matching (PSM) solution, which corresponds to the probability of being treated, conditional on the covariates.

There are several assumptions to be made when applying this method:

- Conditional independence: after conditioning on a set of covariates, the assignment to the TG is independent of the potential outcomes.
- Common support: for any value of the covariates, we can find observations with treatment and without treatment.
- Propensity score balancing of covariates: similar propensity scores are based on similar observed covariates.

A binary logit or probit model is usually used to estimate the following propensity score:

$$P(X_i) = P(DS_i = 1 \,|X_i) = E(DS_i \,|X_i) = X_i\beta + \varepsilon_i \quad (1)$$

where $P(X_i)$ is the probability of receiving the treatment, X is the covariate matrix (the observable characteristics of the farmers and their farms presented in Table 1), β is the vector of coefficients to be estimated, DS is a dichotomous variable equal to 1 if the farmer is a direct seller for the year under consideration and 0 otherwise, $i = 1, \dots, n$ denotes the observations at the farm level and ε_i is the error term.

This value of the propensity score is then used to estimate the average treatment effect (ATE) using matching methods where each farmer treated is associated with one or more nearby farmers in the CG.

Once individuals are matched, the impact of direct selling on the sustainability of a farm is measured by the average treatment effect on the individual treated (ATT) defined by the following formula:

$$ATT = E[Y_i(1) - Y_i(0) \mid DS_i = 1] \quad (2)$$

where Y is the dependent variable (sustainability), $Y_i(1)$ corresponds to the dependent variable for the TG and $Y_i(0)$ corresponds to the dependent variable for the CG farmer i.

Another method also used in the literature is the difference-in-differences (DID) method. This method consists of calculating the treatment effect by comparing the average change in the dependent variable over time for the TG and for the CG (Bryson et al., 2002). The ATE can be expressed as follows:

$$\begin{aligned} ATE = ATT = \ & E[Y_i(1) - Y_i(0)] \\ = \ & \{E[Y|X, DS = 1, T = 1] - E[Y \mid X, DS = 0, T = 1]\} \\ - \ & \{E[Y \mid X, DS = 1, T = 0] - E[Y \mid X, DS = 0, T = 0]\} \end{aligned} \quad (3)$$

where Y is the dependent variable, $DS = 1$ if the farmer is a direct seller and 0 otherwise, and $T = 1$ in 2016 and $T = 0$ in 2010.

This method has the advantage of being time-inclusive and allows for unobservable but fixed characteristics over time (Weldegebriel, 2016). However, the validity of the estimates depends on the strong assumption that the TG and CG follow the same time trend in the absence of treatment (Smith & Todd, 2005; Weldegebriel, 2016). This assumption may be difficult to test if two groups have widely divergent characteristics. The results may therefore be biased if changes over time depend on the initial characteristics of the individuals.

This problem can be solved by applying PSM to the DID method. This approach (PSM-DID) consists in matching treated individuals with similar untreated individuals with regard to observable characteristics by using a kernel method, and then applying DID to the matched individuals (Heckman et al., 1997; Villa, 2012; Weldegebriel, 2016). The kernel matching consists in comparing the propensity score of each treated individual to a weighted average of the propensity scores of all untreated individuals, with the highest weight given to individuals with propensity scores closest to those of the treated individuals. These two methods are complementary since they allow to correct for any selection bias due to observable or unobservable characteristics that are expected to influence treatment effect, and thus to accurately measure the treatment effect by comparing the TG to the CG (Heinrich et al., 2010). The PSM-DID model is shown in Equation (4).

$$Y_{it} = \ \beta_0 + \beta_1 DS_{it} \times T_{it} + \beta_2 X_{it} + \varepsilon_{it} \quad (4)$$

Where Y_{it} is the sustainability of farm i at time t, $DS_{it} = 1$ are treated farms and $DS_{it} = 0$ are the untreated farms, $T_{it} = 1$ in 2016 and $T_{it} = 0$ in 2010. X_{it} represents the observable characteristics of the farmers and their farms used for matching. ε_{it} is the error term.

6. Results

6.1. Descriptive statistics

We notice an overall increase in direct sales between 2010 and 2016 in France, especially in metropolitan France and Guadeloupe. Except for Reunion, the overseas territories seem to rely more on direct sales than metropolitan France (Table 2).

Table 2 Marketing channels adopted by farms

	2010

	Metropolitan France (N = 4433)	Martinique (N = 234)	Guadeloupe (N = 505)	Reunion (N = 886)	Total (N = 6058)
Intermediated sale only	3447	122	309	695	4573
(%)	(77.76)	(52.14)	(61.19)	(78.44)	(75.49)
Long supply chains only	3231	81	231	665	4208
(%)	(72.89)	(34.62)	(45.74)	(75.06)	(69.46)
Indirect sale only	216	41	78	30	365
(%)	(4.87)	(19,52)	(15.45)	(3.38)	(6.03)
Direct sale*	986	112	196	191	1485
(%)	(22.24)	(47.86)	(38.81)	(21.56)	(24.51)
	2016				
	Metropolitan France (N = 4433)	**Martinique (N = 234)**	**Guadeloupe (N = 505)**	**Reunion (N = 886)**	**Total (N = 6058)**
Intermediated sale only	3349	160	292	735	4536
(%)	(75.55)	(68.38)	(57.82)	(82.96)	(74.88)
Long supply chains only	3086	98	192	592	3968
(%)	(69.61)	(41.88)	(38.02)	(66.82)	(65.50)
Indirect sale only	263	62	100	143	568
(%)	(5.94)	(26.5)	(19.8)	(16.14)	(9.38)
Direct sale*	1084	74	213	151	1522
(%)	(24.45)	(31.62)	(42.18)	(17.04)	(25.12)

* Farmers selling without intermediaries may also combine their marketing channels and sell to intermediaries
Source: The authors.

We provide descriptive statistics of quantitative variables along with t-tests for difference in means in Table 3a and descriptive statistics of qualitative variables along with Khi2 independence tests in Table 3b. The descriptive statistics highlight the differences in evolution observed over the period 2010-2016, between the TG and the CG. These evolutions refer not only to the sustainability indicators but also to the farmers' individual characteristics and the structural characteristics of their farm.

Table 3a Descriptive statistics of quantitative variables

	2010											
	Martinique (N = 122)			**Guadeloupe (N = 307)**			**Reunion (N = 694)**					
	Diff.	CG	TG	Diff.	CG	TG	Diff.	CG	TG	Diff.	CG	TG
	-8.13	5.10	5.06	0.04	11.06	6.43	4.62					
	-36991.3	25572.5	32931.6	-7359.1	49191.7	30090.3	19101.4					
	-1.86	1.18	1.29	-0.11	1.93	1.69	0.24					
	-2.80	0.47	1.04	-0.57	1.61	2.06	-0.44					
	-0.05*	0.05	0.03	0.02	0.02	0.01	0.01					
	-0.07	1.51	1.43	0.08	1.14	1.33	-0.19***					

	Metropolitan France (N = 3440)				
Variable	CG	TG	Diff.	CG	TG
Farmers'and farms'characteristics:					
UAA	1154.59	66.35	88.24**	19.23	27.36
Economic sustainability:					
SGP	362651.3	265588.9	97062.5	76556.4	113547.2
Socio-territorial sustainability:					
Employment	3.70	4.42	-0.72	2.20	4.06
Permanent employment	21.27	19.53	1.74	1.04	3.85
External employment	0.26	0.17	0.09	0.01	0.06
Agro-ecological sustainability:					
Inter-crop diversification	2.58	2.30	0.28***	1.16	1.23

Table 3a (continued)

	2016											
	Metropolitan France (N = 3440)			**Martinique (N = 122)**			**Guadeloupe (N = 307)**			**Reunion (N = 694)**		
Variable	CG	TG	Diff.	CG	TG	Diff.	CG	TG	Diff.	CG	TG	Diff.
Farmers'and farms'characteristics:												
UAA	162.39	74.90	87.49***	16.37	28.94	-12.57	5.73	5.24	0.49	10.83	6.44	4.38
Economic sustainability:												
SGP	348092.9	405139.0	-57046.0	67709. 4	93340.4	-25631. 1	26251.9	34994. 7	-8742.8	49660.6	31178.2	18482.4
Socio-territorial												
Employment	4.04	5.26	-1.22	1.34	3.48	-2.15**	1.16	1.36	-0.21	2.29	1.57	0.72
Permanent employment	42.90	47.55	-4.65*	9.72	15.38	-5.66	5.26	5.21	0.06	9.24	8.22	1.02
External employment	0.53	0.33	0.20	0.04	0.02	0.02	0.14	0.02	0.12	0.02	0.01	0.00
Agro-ecological sustainability:												
Inter-crop diversification	2.47	2.37	0.10	1.30	1.62	-0.31	1.60	1.69	-0.09	1.08	1.23	-0.16-***
Intra-crop diversification	0.32	0.32	0.00	0.17	0.42	-0.26*	0.07	0.54	-0.48***	0.04	0.05	-0.02

CG denotes the mean value of the variable for farmers in the control group, TG the mean value of the variable for farmers in the treatment group and Diff the difference in mean between the two groups.
Source: The authors.

Table 3b Descriptive statistics of qualitative variables

		2010							
		Metropolitan France (N=3440)		**Martinique (N=122)**		**Guadeloupe (N=307)**		**Reunion (N=694)**	
Variable		**CG**	**TG**	**CG**	**TG**	**CG**	**TG**	**CG**	**TG**
Farmers'and farms'characteristics:									
Education	No diploma	2.69	4.06	57.29	26.92	42.18	37.50	51.37	57.53
	Secondary	68.97	68.75	38.54	53.85	49.29	53.13	41.71	35.62
	Higher	28.33	27.19	4.17	19.23	8.53	9.38	6.92	6.85
	χ^2	2.07		11.15***		0.60		1.07	
Main activity	Yes	71.57	85.31	73.96	84.62	25.59	46.88	83.41	72.60
	No	28.43	14.69	26.04	15.38	74.41	53.13	16.59	27.40
	χ^2	27.71***		1.28		13.68***		5.24**	
Sustainability indicators:									
Processing	Yes	0.58	2.81	-	-	-	-	-	-
	No	99.42	97.19	-	-	-	-	-	-
	χ^2	18.63***		-		-		-	
Turnover from diversification	Yes	2.21	4.06	-	-	-	-	1.45	-
	No	97.79	95.94	-	-	-	-	98.55	-
	χ^2	4.27**		-		-		0.70	
Tourism	Yes	2.88	4.69	-	-	-	-	0.49	-
	No	97.12	95.31	-	-	-	-	99.52	-
	χ^2	3.19*		-		-		4.65**	
Quality signs	Yes	27.05	31.56	6.27	11.54	-	-	0.48	-
	No	72.95	68.44	93.75	88.46	-	-	99.52	-
	χ^2	2.96*		0.84		-		0.35	
Organic certification	Yes	5.00	19.38	-	-	-	-	-	-
	No	95.00	80.63	-	-	-	-	-	-
	χ^2	101.04***		-		-		-	

Table 3b (continued)

		2016							
		Metropolitan France (N=3440)		**Martinique (N=122)**		**Guadeloupe (N=307)**		**Reunion (N=694)**	
Variable		**CG**	**TG**	**CG**	**TG**	**CG**	**TG**	**CG**	**TG**
Farmers'and farms'characteristics:									
Education	No diploma	6.35	7.81	6.25	15.38	6.16	10.42	16.10	12.33
	Secondary	69.07	67.81	90.63	84.62	90.52	89.58	81.96	83.56
	Higher	24.58	24.38	3.13		3.32		1.93	4.11
	χ^2	1.03		2.34		2.94		2.05	
Main activity	Yes	69.71	86.25	82.29	80.77	28.91	56.25	85.02	75.34
	No	30.29	13.75	17.71	19.23	71.09	43.75	14.98	24.66
	χ^2	38.75***		0.03		21.05***		4.56**	
Sustainability indicators:									
Processing	Yes	-	-	-	-	-	-	-	-
	No	-	-	-	-	-	-	-	-
	χ^2	-		-		-		-	
Turnover from diversification	Yes	2.15	4.06	3.13	11.54	-	-	0.81	-
	No	97.85	95.94	96.88	88.46	-	-	99.19	-
	χ^2	4.69**		3.10*		-		0.59	
Tourism	Yes	2.66	5.31	-	-	-	-	0.64	-
	No	97.34	94.69	-	-	-	-	99.36	-
	χ^2	7.23***		-		-		0.47	
Quality signs	Yes	29.46	22.81	9.38	11.54	1.90	-	1.93	-
	No	70.54	77.19	90.63	88.46	98.10	-	98.07	-
	χ^2	6.24**		0.11		0.30		1.44	
Organic certification	Yes	6.57	23.44	-	-	-	-	0.64	4.11
	No	93.43	76.56	-	-	-	-	99.36	95.89
	χ^2	110.43***		-		-		7.86***	

*, ** and *** respectively denote significance at the 10%, 5% and 1% levels. CG denotes the control group, TG the treatment group
Source: The authors.

Regarding the farmers' individual characteristics, we notice that the farmers from Martinique in the TG are better educated in 2010. In general, a larger proportion of producers in the TG have no education at all, regardless of the area considered. In addition, relatively more of these producers spend more than three-quarters of their time on their farms. Therefore, farms using direct marketing chains usually have farming as their main activity. Regarding the structural characteristics of the farms, the metropolitan farmers from the TG have a significantly smaller UAA in 2010 and 2016. For the overseas farmers, these differences are smaller but highlight a smaller area of farms in the TG in Guadeloupe and Reunion.

Concerning the sustainability indicators, we cannot analyze the differences in terms of non-agricultural diversification (product processing or tourism activities) and in terms of label use (organic farming or quality signs) in the overseas farms because these initiatives are poorly developed there, regardless of the marketing method considered. In metropolitan France, farmers in the TG more frequently have organic agriculture certification or implement other quality signs. They are also more involved in processing and tourism activities. However, regardless of geographic location, there is no difference in terms of standard gross production or employment. In terms of agricultural diversification, all farmers selling directly offer a greater variety of market gardening products in 2010 and 2016.

Comparing the sustainability of farms in the TG and the CG is only possible if we control for the individual and structural characteristics that conditioned the adoption of the direct sales marketing strategy. We find important differences between the TG and CG, particularly in terms of area, education and time spent on the farm. These elements confirm the importance of farmers' and farms' characteristics in adopting an innovation and form the basis of the propensity score matching method to define a common baseline for comparison between the TG and the CG.

6.2. Econometric models

We first provide our results of the probit estimations in Table 4. Our results confirm the influence of education, UAA and being a full-time farmer on the probability to adopt direct sales marketing. More precisely, the lower the UAA, the higher the probability to turn to direct sales for metropolitan farmers. The education level also seems to have a positive impact on direct sales adoption but only in Martinique. The fact that the farmer works full time on the farm has a positive impact on direct sales adoption in Metropolitan France and Guadeloupe but a negative impact in Reunion. All metropolitan regions were accounted for in the first estimation model. The rates of correct classification reveal a good fit of the models with rates ranging from 65 % to 91 %.

Table 4 Probit estimations of the PSM model

		Metropolitan France (N=3422)	**Overseas (N=1123)**	**Martinique (N=122)**	**Guadeloupe (N=307)**	**Reunion (N=694)**
Education	No diploma			Reference		
	Secondary	0.04	0.12	0.66**	0.16	-0.11
	Higher	0.17	0.27	1.54***	0.28	0.0003
Main activity		0.43***	-0.18*	0.47	0.64***	-0.31**
UAA		-0.002***	-0.001	-0.001	-0.02	-0.01
cons		-1.16***	-0.90***	-1.60***	-0.73***	-0.91***
Classification rate		90.79 %	82.64 %	79.51 %	65.15 %	89.48 %

*, ** and *** respectively denote significance at the 10%, 5% and 1% levels.
Source: The authors.

The PSM-DID modeling in Table 5 allows us to measure the impact of direct sales on farms' sustainability, independent of any individual characteristics of the farm manager or any structural characteristics of their farm.

Table 5 Results from PSM-DID model

		Metropolitan France (N = 6852)	Overseas (N = 2240)	Martinique (N = 214)	Guadeloupe (N = 610)	Reunion (N = 1388)
Economic sustainability						
SGP	α	62000	2613.55	195.34	9789.57*	-27000
	α+δ	210000***	5692.13	-6900	13000**	-32000
	δ	140000***	3078.58	-7100	3204.32	-557.60
UAA	α	-7.87	-0.60	-2.15	0.27	-0.27
	α+δ	-8.41	0.71	8.69	0.003	-0.43
	δ	-0.54	1.30	10.84	-0.26	-0.16
Processing	α	0.02***	0.01***	0.04**	-0.004	0.02***
	α+δ	0.003	0.00	0.00	0.00	0.00
	δ	-0.02***	-0.01**	-0.04	0.004	-0.02**
Turnover diversification	α	0.01*	0.01	0.003	-0.00	0.01
	α+δ	0.01**	0.01**	0.11**	0.02**	-0.01
	δ	0.002	0.01	0.11	0.02	0.02
Socio-territorial sustainability						
Employment	α	0.68*	0.20	0.54	0.10	0.02
	α+δ	1.35***	0.01	1.70	0.28	-0.44
	δ	0.68	-0.19	1.16	0.18	-0.46
Permanent employment	α	-2.00	0.81	-1.90	0.76	0.91
	α+δ	5.82***	-0.43	-6.24	-0.52	0.39
	δ	7.81***	-1.25	-4.32	-1.28	-0.53
External employment	α	-0.03	-0.00	0.05	-0.03*	-0.01
	α+δ	-0.22***	-0.04*	-0.01	-0.01	-0.004
	δ	-0.19*	-0.04	-0.06	0.01	0.001
Tourism	α	0.02***	0.01	0.04**	-	0.02***
	α+δ	0.03***	-0.00	0.00	-	-0.01
	δ	0.01	-0.02**	-0.04	-	-0.01***
Quality signs	α	0.05***	0.00	0.02	-0.00	-0.01
	α+δ	-0.04***	-0.01	-0.05	-0.01	-0.02***
	δ	-0.09***	-0.01	-0.07	-0.01	-0.02**
Organic certification	α	0.13***	0.01*	-	0.00	0.03***
	α+δ	0.16***	0.02***	-	0.01*	0.03***
	δ	0.03*	0.01	-	0.01	0.01
Agro-ecological sustainability						
Inter-crop diversification	α	-0.11**	0.11**	-0.07	-0.14	0.19***
	α+δ	0.04	0.26***	0.21	0.05	0.16***
	δ	0.16*	0.15**	0.27	0.19	-0.03
Intra-crop diversification	α	0.17***	0.19***	-0.16	0.32***	0.01
	α+δ	0.10***	0.29***	0.27*	0.44***	0.02
	δ	-0.06**	0.10**	0.43**	0.12	0.01

*, ** and *** respectively denote significance at the 10%, 5% and 1% levels.

δ : Average treatment effect

α : difference between TG and CG in 2010.

α+δ : difference between TG and CG in 2016.

Source: The authors.

In terms of economic sustainability, we note that farmers in the TG have seen their production potential increase in metropolitan France and in Guadeloupe in 2016 (as shown by the coefficients α+δ). In particular, the average

SGP increased more between 2010 and 2016 in the TG than in the CG in metropolitan France (as shown by the coefficient δ). The evolution observed in Martinique and Reunion remains comparable between the TG and the CG (*H1 partially validated*). This dynamic is independent from any evolution of farm size, which remains comparable between the two groups over this period *(H2 not validated)*. Moreover, direct sales appear to be linked to a lower processing activity *(H3 not validated).* While farms in the TG are more likely to develop their processing activity in 2010, in 2016 they are more likely to stop this activity than farms in the CG. Finally, the probability of achieving a turnover from diversification activities of more than 10% is higher for farms in the TG in 2016 regardless of location, with the exception of Reunion. However, the average change over time between groups is not significantly different *(H4 partially validated)*.

Regarding the socio-territorial sustainability, we have assumed that direct sales activities rely on skills different from the ones needed for the agricultural activity and require a larger workforce. Developing a processing activity in parallel also calls on specific skills and the farmers do not necessarily have all these skills or a sufficient workforce to develop all these activities. While in the overseas departments, the evolution of the level of employment is comparable for both groups *(H5 not validated)*, farms in the TG located in metropolitan France employ more permanent labor (*H6 partially validated*), to the detriment of external labor *(H7 partially validated).* Farmers seem to be refocusing on their farms and taking on all the tasks related to their production internally by relying less on company personnel (ETA, CUMA), groups of employers and other service providers. By concentrating their activity internally, these farms reduce their dependence on external labor. Furthermore, there is no difference in metropolitan France between the TG and CG over time concerning tourism activities, but a more limited development of these activities in Reunion *(H8 not validated).* The development of other activities such as product processing or tourism is therefore not automatically associated with direct sales for treated farms. Finally, it can be seen that metropolitan farms in the TG focus on organic agriculture certification when selling their products directly to consumers, to the detriment of other quality signs such as PGI or *"Label rouge" (H9 not validated and H10 partially validated*). In the overseas, while farms in the TG rely more on organic certification in 2016, there is not significant difference over time between the two groups to validate the positive effect of direct sales on certification. The multiplication of quality signs only seems relevant for the farms in the CG that do not address consumers directly but through intermediaries. For direct sales, organic certification seems to be the only one necessary to meet consumers' requirements. Hence, each certification, even if its vocation is to meet environmental requirements, is aimed at a specific actor. While PGI and *"Label rouge"* meet the requirements of the supply chain, organic certification is aimed at consumers.

In terms of agro-ecological sustainability, strengthening production under the organic label translates into the implementation of a sustainable agricultural management system, notably through improved soil quality, natural resource management and the development of biodiversity. This adequacy between consumers' expectations and environmental issues is also observed through the development of a more diversified intra- and inter-farm production, observed in most of the locations considered *(H11 and H12 validated).* By offering consumers a wide range of products, treated farms meet consumers' as well as environmental requirements. Crop diversification is indeed associated with a lower use of inputs and thus a reduction of environmental impacts (Meynard et al., 2013).

7. Conclusion and discussion

Since the early 2000s, initiatives aimed at reducing the number of intermediaries and promoting sustainable forms of agriculture have multiplied, particularly through the resurgence of direct sales. The development of this marketing method, seen as an innovation (Chiffoleau & Prévost, 2013; Vaillant et al., 2017) raises questions about its capacity to respond to the challenges of farms' economic, socio-territorial and agro-ecological sustainability.

The objective of this research is to analyze the impact of the development of a marketing strategy, more precisely direct sales, on the three pillars of sustainability for farms specializing in market gardening in metropolitan France and in three overseas departments: Martinique, Guadeloupe and Reunion. The comparison of these territories is all the more relevant as they all have to meet national and European requirements for the reduction of plant protection products and the strengthening of quality agriculture, but each one evolves in specific organizational, agronomic and climatic conditions.

We conducted a dynamic analysis of farms using data from the 2010 agricultural census as well as from the farm structure survey conducted in 2016. These data allow us to consider the structural characteristics of the farms, the characteristics of the farmers as well as their geographical location. Since farmers turning to direct sales have different characteristics from other farmers, we perform a propensity score matching coupled with a difference-in-differences analysis. This approach allows us to measure the impact of direct sales on farms' sustainability independent of any propensity to adopt this marketing method.

Our results show a lesser effect of direct sales on farms' sustainability for island economies compared to metropolitan France. Whatever the location, direct sales result in a greater diversification of production: diversification in market gardening production on the one hand and of other forms of production on the other. This double diversification meets the requirements of consumers, who want to benefit from a variety of products at a point of sale. While direct sales result in greater diversification, they are not synonymous with labeled production in island economies, where the products marketed are not more certified than in other marketing channels. In metropolitan France, we note that farmers marketing via direct sales prefer organic certification to the detriment of other certifications, which are adopted more frequently by other farmers marketing through intermediaries. Only organic certification seems to meet consumers' requirements for product quality. Regardless of the location, it can be seen that farmers marketing via direct sales are abandoning some diversification activities, particularly processing and tourism. This shows that, in the absence of favorable conditions for combining direct sales and diversification activities, farmers refocus on their productive activity and its marketing. Finally, the results show that only farmers marketing via direct sales and located in metropolitan France see an increase in their potential output and in the proportion of permanent employees.

In island economies, marketing via short food supply chains is often coupled with marketing via long food supply chains (Maréchal & Spanu, 2010; Malak-Rawlikowska et al., 2019; Alonso Ugaglia et al., 2020). Direct sales therefore appear as an additional marketing channel to those involving at least one intermediary. In this context, and in contrast to metropolitan France, the productive strategy is not more economically valued. No production differentiation strategy in terms of certification is developed there, whereas in metropolitan France, direct sales appear to be a marketing method which valorizes the productive efforts economically, translating into the development of more environmentally-friendly production.

Even though metropolitan France and the island economies benefit from the same institutional rules, the impact of direct sales on farms' sustainability is weaker in these territories. In order to take account of and measure the importance of the environment in which farmers operate, a more detailed analysis of the interdependencies of the farmers with the other actors of the sector is essential.

Conflict of interest On behalf of all authors, the corresponding author states that there is no conflict of interest.

References

Agreste. (2011a). *Recensement agricole 2010 France métropolitaine : Premières tendances*. *Agreste Primeur(266)*. Available online: https://sg-proxy02.maaf.ate.info/IMG/pdf_primeur266-2.pdf

Agreste. (2011b). *Guadeloupe, premières tendances*. *Agreste Guadeloupe*(10). Available online: https://sg-proxy02.maaf.ate.info/IMG/pdf_D97111A02-2.pdf

Agreste. (2011c). *Martinique, premières tendances*. *Agreste Martinique*(7). Available online: https://sg-proxy02.maaf.ate.info/IMG/pdf_D97211A01-2.pdf

Agreste. (2011d). *Réunion, premières tendances*. *Agreste Spécial*(70). Available online: https://sg-proxy02.maaf.ate.info/IMG/pdf_D97411A01-2.pdf

Agreste. (2022). *Surface moyenne des exploitations agricoles en 2020 : 69 hectares en France métropolitaine et 5 hectares dans les DOM*. *Agreste Primeur*(13). Available online: https://agreste.agriculture.gouv.fr/agreste-web/download/publication/publie/Pri2213/Primeur%202022-13_RA2020_%20VersionD%C3%A9finitive.pdf

Alonso Ugaglia, A., Del'homme, B., Lemarié-Boutry, M., & Zahm, F. (2020). Le rôle des circuits courts et de proximité dans la performance globale des exploitations agricoles. *Reflets et perspectives de la vie économique*, *LVIII*(1), 19-34. https://doi.org/10.3917/rpve.591.0019

Aubert, M. (2016). Commercialisation des produits agricoles en circuit court : Analyse du cas français. *Systèmes alimentaires / Food Systems*, *1*, 121-145. https://doi.org/10.15122/isbn.978-2-406-06863-1.p.0121

Aubert, M. (2017). *Quantifier ou l'art de mesurer l'utilisation des produits phytosanitaires : Analyse empirico-formelle de la gestion sanitaire et environnementale des producteurs horticoles*. [Thèse de doctorat Science économique, MontpellierSupAgro].

Aubert, M., & Enjolras, G. (2014). Do short food supply chains go hand in hand with environment-friendly practices? An analysis of French farms. *International Journal of Agricultural Resources, Governance and Ecology*, *12*(2), 189. https://doi.org/10.1504/IJARGE.2016.076932

Aubert, M., & Enjolras, G. (2016). Analyse financière des exploitations fruitières et maraîchères françaises qui vendent au détail. *Économie rurale. Agricultures, alimentations, territoires*, *356*, Article 356. https://doi.org/10.4000/economierurale.5076

Aubry, C., & Chiffoleau, Y. (2009). Le développement des circuits courts et l'agriculture péri-urbaine : Histoire, évolution en cours et questions actuelles. *Innovations Agronomiques*, *5*, 53-67. https://hal.archives-ouvertes.fr/hal-01197823

Azam, M., & Banumathi, M. (2015). The role of demographic factors in adopting organic farming : A logistic model approach. *International Journal of Advanced Research*, *3*, 713-720.

Baret, P. (2006). Chapitre 6. L'évaluation contingente de la Performance Globale des Entreprises : Une méthode pour fonder un management sociétalement responsable ? In *Responsabilité Sociale de l'Entreprise* (p. 135). De Boeck Supérieur. https://hal.archives-ouvertes.fr/hal-02147330

Berthelot, C. (2003). *Quels enjeux et quels développements pour les agriculteurs des départements d'outre-mer ?* (p. 207). Conseil Économique et Social.

Blazy, J.-M., Carpentier, A., & Thomas, A. (2011). The willingness to adopt agro-ecological innovations : Application of choice modelling to Caribbean banana planters. *Ecological Economics*, *72*, 140-150. https://doi.org/10.1016/j.ecolecon.2011.09.021

Briquel, V., Vilain, L., Bourdais, J. L., Girardin, P., Mouchet, C., & Viaux, P. (2001). La méthode IDEA (indicateurs de durabilité des exploitations agricoles) : Une démarche pédagogique. *Ingénieries eau-agriculture-territoires*, *25*, 29-39. https://hal.archives-ouvertes.fr/hal-00464508

Bryson, A., Dorsett, R., & Purdon, S. (2002). *The use of propensity score matching in the evaluation of active labour market policies* [LSE Research Online Documents on Economics]. London School of Economics and Political Science, LSE Library. https://econpapers.repec.org/paper/ehllserod/4993.htm

Capt, D., & Wavresky, P. (2014). Determinants of direct-to-consumer sales on French farms. *Revue d'Études en Agriculture et Environnement*, *95*, 351-377. https://doi.org/10.4074/S1966960714013046

Caswell, M., Fuglie, K., Cass, Ingram, ra, & Kascak, C. (2001). *Adoption of Agricultural Production Practices : Lessons Learned from the U.S. Department of Agriculture Area Studies Project*. http://www.ers.usda.gov/publications/pub-details/?pubid=41202

Chiffoleau, Y., & Prévost, B. (2013). Les circuits courts, des innovations sociales pour une alimentation durable dans les territoires. *Norois*, *3*, 7-20.

DAAF Réunion. (2019). *La filière fruits et légumes*. https://daaf.reunion.agriculture.gouv.fr/Fruits-et-legumes. Accessed 20 Sept. 2021.

Davies, M., & Buisine, S. (2017). La culture d'innovation dans les organisations françaises. *Technologie et innovation*, *17*. https://doi.org/10.21494/ISTE.OP.2017.0160

Debbahi, Y., & Kerzabi, A. (2015). Innovation : Facteur de compétitivité dans l'économie de connaissances. *Revue Les Cahiers du POIDEX*, *4*(1), 49-59. https://www.asjp.cerist.dz/en/article/44317

Delcombel, E. (2005). *Organisation de l'action collective et rôle de la puissance publique pour le développement de l'agriculture guadeloupéenne : Les difficultés du modèle coopératif et de la concertation entre acteurs* [These de doctorat, Antilles-Guyane]. https://www.theses.fr/2005AGUY0125

Deressa, T. T., Hassan, R. M., Ringler, C., Alemu, T., & Yesuf, M. (2009). Determinants of farmers' choice of adaptation methods to climate change in the Nile Basin of Ethiopia. *Global Environmental Change*, *19*(2), 248-255. https://doi.org/10.1016/j.gloenvcha.2009.01.002

Elkington, J. (1998). *Cannibals with Forks : The Triple Bottom Line of 21st Century Business*. New Society Publishers.

FAO. (2021). *Fruit and vegetables : Opportunities and challenges for small-scale sustainable farming*. FAO, CIRAD. https://doi.org/10.4060/cb4173en

Feder, G., Just, R. E., & Zilberman, D. (1985). Adoption of Agricultural Innovations in Developing Countries : A Survey. *Economic Development and Cultural Change*, *33*(2), 255-298. https://doi.org/10.1086/451461

Fernandez-Cornejo, J., Beach, E., & Huang, W.-Y. (1994). The Adoption of IPM Techniques By Vegetable Growers in Florida, Michigan and Texas. *Journal of Agricultural and Applied Economics*, *26*. https://doi.org/10.1017/S1074070800019271

François, M., Moreau, R., & Sylvander, B. (2013). *Agriculture biologique en Martinique. Quelles perspectives de développement ?* IRD Éditions. http://books.openedition.org/irdeditions/2770

Freguin, S., Angeon, V., & Cortes, G. (2020). *Les petites agricultures familiales en Guadeloupe : Une contribution à l'ancrage de l'alimentation ? Résumé exécutif de l'Atelier professionnel du Master EDEV 2019-2020* [Monograph]. CIRAD. https://agritrop.cirad.fr/596771/

Genius, M., Pantzios, C. J., & Tzouvelekas, V. (2006). Information Acquisition and Adoption of Organic Farming Practices. *Journal of Agricultural and Resource Economics*, *31*(1), 93-113. https://www.jstor.org/stable/40987308

Heckman, J., Ichimura, H., & Todd, P. (1997). Matching As An Econometric Evaluation Estimator : Evidence from Evaluating a Job Training Programme. *Review of Economic Studies*, *64*, 605-654. https://doi.org/10.2307/2971733

Heinrich, C., Maffioli, A., & Vázquez, G. (2010). A Primer for Applying Propensity-Score Matching. In *SPD Working Papers* (Nº 1005; SPD Working Papers). Inter-American Development Bank, Office of Strategic Planning and Development Effectiveness (SPD). https://ideas.repec.org/p/idb/spdwps/1005.html

Ilbery, B. W. (1991). Farm diversification as an adjustment strategy on the urban fringe of the West Midlands. *Journal of Rural Studies*, *7*(3), 207-218. https://doi.org/10.1016/0743-0167(91)90085-7

Issor, Z. (2017). « La performance de l'entreprise : Un concept complexe aux multiples dimensions ». *Projectics / Proyectica / Projectique*, *n°17*(2), 93-103. https://www.cairn.info/revue-projectique-2017-2-page-93.htm

Jarzębowski, S., Bourlakis, M., & Bezat-Jarzębowska, A. (2020). Short Food Supply Chains (SFSC) as Local and Sustainable Systems. *Sustainability*, *12*(11), Article 11. https://doi.org/10.3390/su12114715

Kirsch, A. (2021). *Circuits courts et vente directe : Tour des idées préconçues*. Agriculture Stratégies. https://www.agriculture-strategies.eu/wp-content/uploads/2021/03/Les-idees-preconcues-sur-les-circuits-courts-et-la-vente-directe_vf2.pdf

Koesling, M., Flaten, O., & Lien, G. (2008). Factors influencing the conversion to organic farming in Norway. *International Journal of Agricultural Resources, Governance and Ecology*, *7*(1-2), 78-95. https://doi.org/10.1504/IJARGE.2008.016981

Laillet, C. (2013). Méthodes et approche économique transversale exploratoire de six familles de produits en circuits courts. *Centre d'études et de ressources sur la diversification*, 24.

Laurent, C. (2001). *Chapitre 19. La multifonctionnalité de l'agriculture*. Presses de Sciences Po. https://www.cairn.info/vers-un-accord-entre-l-europe-et-le-mercosur--9782724608569-page-407.htm

Le Clanche, J.-F., & Pluvinage, J. (2011). Innovations et alternatives en agriculture : Des initiatives à qualifier. *Pour*, *212*(5), 31-38. https://doi.org/10.3917/pour.212.0029

Ludovic, T., Marie, P., & Bakry, F. (2008). Les déterminants de la compétitivité des filières bananes de Martinique et de Guadeloupe. *Économie rurale*. https://doi.org/10.4000/economierurale.352

Malá, Z., & Malý, M. (2013). The determinants of adopting organic farming practices : A case study in the Czech Republic. *Agricultural Economics (Zemědělská Ekonomika)*, *59*(No. 1), 19-28. https://doi.org/10.17221/10/2012-AGRICECON

Malak-Rawlikowska, A., Majewski, E., Wąs, A., Borgen, S. O., Csillag, P., Donati, M., Freeman, R., Hoàng, V., Lecoeur, J.-L., Mancini, M. C., Nguyen, A., Saïdi, M., Tocco, B., Török, Á., Veneziani, M., Vittersø, G., & Wavresky, P. (2019). Measuring the Economic, Environmental, and Social Sustainability of Short Food Supply Chains. *Sustainability*, *11*(15), Article 15. https://doi.org/10.3390/su11154004

Maréchal, G., & Spanu, A. (2010). Les circuits courts favorisent-ils l'adoption de pratiques agricoles plus respectueuses de l'environnement ? *Le Courrier de l'environnement de l'INRA*, *59*, 33-45. https://hal.archives-ouvertes.fr/hal-01435709

McNally, S. (2001). Farm diversification in England and Wales—What can we learn from the farm business survey? *Journal of Rural Studies*, *17*(2), 247-257. https://doi.org/10.1016/S0743-0167(00)00050-4

Métouolé Méda, Y. J., Egyir, I., Zahonogo, P., Jatoe, J., & Atewamba, C. (2018). Institutional factors and farmers' adoption of conventional, organic and genetically modified cotton in Burkina Faso. *International Journal of Agricultural Sustainability*, *16*, 1-14. https://doi.org/10.1080/14735903.2018.1429523

Meynard, J.-M., Messéan, A., Charlier, A., Charrier, F., Fares, M., Bail, M. L., Magrini, M.-B., & Savini, I. (2013). Freins et leviers à la diversification des cultures : Étude au niveau des exploitations agricoles et des filières. *OCL*, *20*(4), Article 4. https://doi.org/10.1051/ocl/2013007

Mwiathi, P. S. (2008). *Factors affecting adoption of organic farming by maize farmers in Meru South District* [Thesis]. https://ir-library.ku.ac.ke/handle/123456789/8672

ODEADOM. (2014). *Etude préalable en vue du soutien et du développement des circuits courts de proximité.* https://www.odeadom.fr/wp-content/uploads/2015/10/Rapport_definitif_ECCPC.pdf

OECD. (2010). *OECD innovation strategy*. https://www.oecd.org/site/innovationstrategy/defininginnovation.htm. Accessed 27 June 2021.

Ormrod, R. K. (1990). Local Context and Innovation Diffusion in a Well-Connected World. *Economic Geography*, *66*(2), 109-122. https://doi.org/10.2307/143741

Porter, M. E. (1980). *Competitive Strategy : Techniques for Analyzing Industries and Competitors*. Free Press.

Pouch, T. (2020). Changer de paradigme productif en agriculture : Leviers et impasses. *Les possibles*, *24 Été*. https://france.attac.org/nos-publications/les-possibles/numero-24-ete-2020/dossier-la-transformation-du-systeme-productif/article/changer-de-paradigme-productif-en-agriculture-leviers-et-impasses. Accessed 13 Sept. 2021.

Rodríguez-Entrena, M., & Arriaza, M. (2013). Adoption of conservation agriculture in olive groves : Evidences from southern Spain. *Land Use Policy*, *34*, 294-300. https://doi.org/10.1016/j.landusepol.2013.04.002

Rosenbaum, P. R., & Rubin, D. B. (1983). The Central Role of the Propensity Score in Observational Studies for Causal Effects. *Biometrika*, *70*(1), 41-55. https://doi.org/10.2307/2335942

Sapbamrer, R., & Thammachai, A. (2021). A Systematic Review of Factors Influencing Farmers' Adoption of Organic Farming. *Sustainability*, *13*(7), Article 7. https://doi.org/10.3390/su13073842

Schumpeter, J. A. (1939). *Business Cycles: A Theoretical, Historical, and Statistical Analysis of the Capitalist Process*. McGraw-Hill Book Company, Inc.

Serebrennikov, D., Thorne, F., Kallas, Z., & McCarthy, S. N. (2020). Factors Influencing Adoption of Sustainable Farming Practices in Europe: A Systemic Review of Empirical Literature. *Sustainability*, *12*(22), 9719.

Smith, A. J., & Todd, E. P. (2005). Does matching overcome LaLonde's critique of nonexperimental estimators? *Journal of Econometrics*, *125*(1), 305-353. https://doi.org/10.1016/j.jeconom.2004.04.011

Toute l'europe. (2019). Le POSEI, une aide européenne pour l'agriculture d'Outre-mer. *Touteleurope.eu*. https://www.touteleurope.eu/l-europe-en-region/le-posei-une-aide-europeenne-pour-l-agriculture-d-outre-mer/. Accessed 9 Sept. 2021.

Vaillant, L., Gonçalves, A., Raton, G., & Blanquart, C. (2017). Transport et logistique des circuits courts alimentaires de proximité : La diversité des trajectoires d'innovation. *Innovations*, *n° 54*(3), 123-147.

Villa, J. M. (2012). Simplifying the estimation of difference in differences treatment effects with Stata. In *MPRA Paper* (Nº 43943; MPRA Paper). University Library of Munich, Germany. https://ideas.repec.org/p/pra/mprapa/43943.html

Weldegebriel, Z. B. (2016). Social Protection and Vulnerability to Climate Shocks: A Panel Data Evidence from Rural Ethiopia. *Ethiopian Journal of the Social Sciences and Humanities*, *12*(2), Article 2. https://doi.org/10.4314/ejossah.v12i2

Zahm, F., Alonso Ugaglia, A., Barbier, J. M., Boureau, H., Del'Homme, B., Gafsi, M., Gasselin, P., Girard, S., Guichard, L., Loyce, C., Manneville, V., Menet, A., & Redlingshöfer, B. (2019). Évaluer la durabilité des exploitations agricoles : La méthode IDEA v4, un cadre conceptuel combinant dimensions et propriétés de la durabilité. *Cahiers Agricultures*, *28*(5), 10. https://doi.org/10.1051/cagri/2019004