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Short food supply chains and the issue of sustainability

A case study of French fruit producers

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Short food supply chains and the issue of sustainability

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Abstract

Purpose - This paper investigates the manifestations and interactions at work between the ecological, environmental and social dimensions of sustainable development and the development of short food supply chains in French fruit production.

Design/methodology/approach - The methodology is based on the theoretical framework associated with short food supply chains and each pillar of sustainability. We use an original database of 176 surveys of peach and apricot producers from the major French production regions. Three composite indicators, one for each traditional pillar of sustainability, are calculated to evaluate a degree of sustainability at farm level. A simultaneous equations model is estimated on the basis of the calculated indicators.

Findings - The results show that in the choice of a supply chain design in the agricultural sector, the search for economic sustainability is opposed to a rationale of environmental and social sustainability, the latter appearing to be independent of one another.

Originality/value - This article complements previous studies on the issue of sustainability in agriculture and more specifically the relationship between the adoption of short food supply chains and the pillars of sustainable development. The model reveals significant interdependencies, thus emphasizing an issue in reconciling economic imperatives with social or environmental requirements.

Keywords: short food supply chains, sustainable development, fruit production, France

1. Introduction

In recent years, the practice of selling through short food supply chains (SFSCs) has been of particular interest, both from a theoretical and practical perspective. SFSCs are “established in parallel to conventional food chains” and “can represent traditional and/or alternative ways of producing, distributing, retailing, and buying food” (Galli and Brunori, 2013). Among other features, SFSCs are fundamentally characterized by “relations of proximity”, either “spatial” or “cultural” between the producer and the consumer (Renting et al., 2003).

According to the classification adopted by the French Ministry of Agriculture and Fisheries (Barry, 2012), SFSCs refer to the “marketing of agricultural products through direct selling or indirect selling when only one intermediary is involved”. Such a definition echoes Peters (2012), for whom SFSCs are “not only focused on the distance between production and sale of the product, but also the number of links in the food supply chain”.

The first results of the agricultural census show that French farmers are increasingly turning to SFSCs. In 2010, nearly 84,000 farmers (about one fifth) sold all or part of their production through SFSCs (Barry, 2012). Several recent articles have focused on the determinants of selling through SFSCs, both in France and abroad (Aubert and Enjolras, 2017; Capt and Wavresky, 2014; Dufour and Lanciano, 2012; Langhade, 2010).

The expansion of selling through SFSCs therefore leads to substantial changes in the way farms operate (Goodman et al., 2012). Many changes relate to the implementation of direct sales and to a reduction in the environmental impact of farms involved in SFSCs (Kneafsey et al., 2013; Penker, 2006; Renting et al., 2003). This dynamic suggests that SFSCs are in line with sustainable practices.

The World Commission on Environment and Development (1987) defined sustainability as the ability “to satisfy current needs without compromising the possibility for future generations to satisfy their own needs”. As shown by Moldan et al. (2012), the definition of sustainability according to the three-traditional economic, social and environmental pillars has long been debated. Bansal (2002) summarizes three important principles - economic growth, social equity and respect for the environment - which can be used as a guideline for assessing business sustainability.

Most existing studies have indeed focused on only one aspect of the sustainability of SFSCs, primarily the environmental pillar (Aubert and Enjolras, 2016; Maréchal and Spanu, 2010; Penker, 2006; Wiese et al., 2012; Wiese et al., 2015) followed by the social pillar (Langhade, 2010; Renting et al., 2013; Wiese et al., 2012; Wiese et al., 2015) and the economic pillar (Ahearn and Sterns, 2013; Kneafsey et al., 2013; Park et al., 2014). By contrast, few studies have simultaneously considered two or three traditional pillars of sustainability (Hernandez et al., 2012; Mastronardi et al., 2015; Matos and Hall, 2007; Yakovleva, 2007). Bloemhof et al. (2015) considers one additional dimension of sustainability, “institutions”, while Galli et al. (2015) add two dimensions, “ethics” and “health”.

This article aims to measure the scope of this interdependence between the pillars of sustainable development through trade calling on SFSCs. While some studies have focused on the motivations of food retailers to engage in corporate socially responsible activities (Piacentini et al., 2010), the aim of this article is to verify if SFSCs provide farms with any guarantee of sustainability. More precisely, the research questions addressed are twofold: how do short food supply chains influence the three traditional pillars of sustainability, and how do these pillars interact within short food supply chains?

This study focuses on French farms, which are a relevant case study because of the commitment of the government in favour of short food supply chains. More precisely, the institutional

framework is founded on two recent laws: the Law for the Modernization of Agriculture (27 July 2010) and the Law for the Future of Agriculture (13 October 2014). Article 230 of the Law for the Modernization of Agriculture provides the framework of the National Food Programme. The actions implemented are mainly designed to encourage proximity between producers and consumers through the development of short food supply chains. Article 1 of the Law for the Future of Agriculture defines agricultural and food policies at the regional and national levels. One of its objectives is to encourage the territorial anchorage of production, transformation and marketing of agricultural products by promoting the development of short food supply chains.

Our methodology benefits from the creation of an original database containing 176 surveys of farms, and more specifically peach and apricot farms from the main French production regions (Rhône-Alpes, Provence-Alpes-Côte d'Azur and Languedoc-Roussillon) as these crops are more often than not marketed through SFSCs (Barry, 2012). Sampling is based on geographical location and the physical size of the farm. The data are extrapolated so that the results are representative of the production regions. The contents of the database explicitly take account of various aspects characterizing farm sustainability including the individual and structural characteristics of the farm (farmed area), its assets (owner, workforce), its financial situation (turnover, debt) and cultural practices (phytosanitary products and their dosage).

We use this database to build scores associated with each of the pillars of sustainability. This composite approach allows us to assess sustainability on a scale which takes account not only of one indicator but of a whole range (Bloemhof et al., 2015; Briquel et al., 2001; Buys *et al.*, 2014; Galli et al., 2015; Mastronardi et al., 2015; Singh *et al.*, 2009; van Der Vorst et al., 2012; Yakovleva, 2007). In addition to the presentation of detailed descriptive statistics, a simultaneous equations model is estimated on the basis of the calculated scores. The simultaneity of the model allows us to determine the extent to which the requirements related to sustainability interact with each other.

Our article is organized as follows. In section 2, we present the literature review related to short food supply chains and sustainability. In section 3, we discuss the methodology for characterizing the pillars of agricultural sustainability. In section 4, we then measure ecological, environmental and social sustainability using scores. In section 5, we characterize the interdependence of the pillars of sustainability by considering the impact of SFSCs on each of these pillars and in section 6, we conclude with a summary of this study and some perspectives for future work.

2. Literature review: short food supply chains and sustainability

2.1 General framework

Placing short food supply chains (SFSCs) at the heart of a sustainability approach in agriculture is a key issue. The protean nature of sustainability comes from the definition of each pillar. Furthermore, interactions between each pillar emphasize the need to understand the extent to which SFSCs are likely to promote the performance and subsistence of farms (Cagliano et al., 2016).

Most works relating to the indicators of sustainability in agriculture essentially use an empirical approach (Briquel et al., 2001; Buys *et al.*, 2014; Singh *et al.*, 2009). They consist of a census of criteria characterizing sustainability. In the same way, some studies aimed at defining SFSCs emphasize their “sustainable” attributes (Renting et al., 2003; Galli and Brunori, 2013).

The conceptual framework for our study therefore relies on an analysis of the literature concerning SFSCs and each of the pillars of sustainability.

2.2 Short food supply chains and economic sustainability

On a theoretical level, SFSCs and economic sustainability should go hand in hand with several factors combining to guarantee the farmer a better income, through direct and indirect effects.

First, selling within SFSCs would indeed appear to be a direct means of increasing the value of the produce. In addition, the transaction, limited to an intermediary at the most, allows the farmer to recover a greater share of the value added (Broderick et al., 2011).

Secondly, indirect effects can be added to these direct effects. Short food supply chains reduce operating costs such as those related to transportation and chemical inputs (Galli and Brunori, 2013; Kottila and Rönni, 2008), which in turn mechanically contributes to a larger margin and operating income.

2.3 Short food supply chains and environmental sustainability

Environmentally speaking, selling within SFSCs translates into a search for quality on the part of the farmer (Marshall and Spanu, 2010; Kottila and Ronni, 2008). Such a practice can take many forms, including reasoned practices or the implementation of organic farming (Aubert and Enjolras, 2016; Wiese et al., 2012). In the same vein, a significant negative relationship appears to exist between the adoption of SFSCs and the intensity of use of phytosanitary products (Aubert and Enjolras, 2017).

Indirect effects can be added to these direct effects. The consumers' search for proximity leads to an overhaul of supply chains in favour of local ones (Ilbery and Maye, 2005). The result is a significant reduction in the transportation of agricultural products, with a beneficial effect on greenhouse gas emissions (Penker, 2006).

2.4 Short food supply chains and social sustainability

One of the main strengths of SFSCs is to promote a close relationship between producers and consumers (Renting et al., 2003), relying essentially on the complementary territorial and social aspects.

The social aspect is reflected in the development of trust between the two parties involved in the trade (Prigent-Simonin and Héroult-Fournier, 2005; Rampl *et al.*, 2012). It is also linked to the use of a larger workforce required by the additional tasks implied by direct and retail selling (Barry, 2012).

The territorial aspect is based on the development of rural territories, facilitated by the extension of SFSCs. The additional workforce previously cited is essentially local (Kneafsey et al., 2013). Consumers are also more sensitive to this dimension within SFSCs than in other supply chains (Ilbery and Maye, 2005).

2.5 Relationship between the pillars of sustainability

A succinct representation of the three traditional pillars reveals a certain dependency between them, itself conditioned by SFSCs. When reviewing recent studies focusing on sustainable food supply

chains, Li et al. (2014) showed that the quest for sustainability is considered as an objective in its own right. Moldan et al. (2014) pointed out that pillars of sustainability have such close and complex relationships that sustainability indicators might encompass several pillars at the same time. In addition, Matos and Hall (2007) highlighted conflicts that arise between pillars, e.g. the well-known balance between economic performance and environment degradation.

Within agri-food supply chains, Galli and Brunori (2013) considered SFSCs as a “driver of change” acting simultaneously on all pillars of sustainability. For example, the proximity provided by SFSCs thus promotes the social pillar, allowing the rural fabric to be maintained and local jobs to be created. It also allows farmers to reduce transportation costs and therefore to increase their income, thereby influencing the economic pillar. Considered together, these two pillars lead farmers to adopt more environmentally-friendly practices, such as reducing greenhouse gas emissions from transport and using fewer chemical inputs.

However, through direct surveys with farmers, Bihannic and Michel-Guillou (2011) showed that the economic pillar appears to be predominant, thereby conditioning the other pillars. While farmers are aware of the stakes related to the environment and natural resources, productivity remains their primary objective.

3. Methodology

In light of the different considerations mentioned above, short food supply chains (SFSCs) seem to have a globally positive influence on the different pillars of sustainability. This result needs to be validated using an appropriate methodology taking account not only of the interaction existing between each pillar but also the conditioning effect of SFSCs on these pillars.

3.1 Database

Data collection aims to offset an incompleteness of data from official French sources relating to fruit-producing farms. Indeed, the environmental dimension of sustainability can currently be assessed through the official surveys of “Agricultural Practices”, offering considerable detail, and the “Agricultural Census” which offers a more aggregated approach. Economic sustainability can be measured using data from the “Farm Accountancy Data Network” (FADN), if only partially because only professional farms - those meeting a minimum economic threshold - are taken into account. Finally, social sustainability can be approximated succinctly through the “Agricultural Census”.

Peach and apricot producers are mainly grouped into 3 major producing regions: Provence-Alpes-Côte-d'Azur (PACA), Languedoc-Roussillon (LR) and Rhône-Alpes (RA). Within these regions, peach and apricot farms play a prominent role. On the basis of the 2010 Agricultural Census data, farms specializing in peach production in the 3 regions considered represent 68.5% of all farms and 88.91% of the farmed area. For farms specializing in apricots, these relative weights are 88.58% and 97.43% respectively.

Data were collected by a research team, to which the authors belonged, from farmers by means of a face-to-face survey. On average interviews lasted one and a half hours in order to take sufficient time to formulate key questions and hence to ensure the quality of the information collected. Our original database included 176 peach and apricot producers located in the three main French production regions.

Farmers were selected by the research team on the basis of a stratification that reproduces the criteria defined by the French Service of Statistics and Forecasting (SSP). More precisely, three criteria were taken into account: the geographic location (region), the productive orientation (economic and technical orientation) and the physical size of farms (farmed area). The farmers surveyed are therefore representative of their sub-population.

More precisely, a first stratum was based on the relative weight of farms in each of the regions considered. A second stratum was then used to differentiate farms according to their physical dimension, with the following thresholds: 1 hectare or less, above 1 hectare to below 5 hectares, 5 to 10 hectares and more than 10 hectares. The productive orientation of farms was not retained as a criterion of differentiation insofar as all the farms surveyed specialize in fruit production. Moreover, as farms producing peaches also generally produce apricots, distinguishing farms according to their main production was not deemed a relevant criterion of differentiation.

On the basis of this double stratification, twelve subpopulations were identified and an extrapolation factor was calculated for each one and allocated to farms so that the farms in a given stratum were representative of all farms in the stratum. This sampling method allowed us to consider all farms in the most neutral way possible: if a farm could not be surveyed, we had to search for an equivalent in the corresponding stratum. Therefore, we could avoid non-response bias (Jayawardhena et al., 2007; Huddleson et al., 2009) and, within each stratum, farmers were randomly selected.

Finally, because the survey was founded on stratified sampling, an extrapolation factor could be calculated for each stratum. As our strata referred to a national classification for which precise information was available, we could calculate and apply these extrapolation factors. Hence, the extrapolation coefficient was defined as the number of farms surveyed in a stratum divided by the total number of farms observed in the 2010 Agricultural Census with the same characteristics. The surveys were conducted in the first quarter of 2013. Insofar as we have more recent and comprehensive data than those provided by the 2010 Agricultural Census, we assumed that the proportion of farms per stratum was constant over the period 2010-2013.

3.2 Statistical and econometric modelling

To take the richness and complexity of each pillar of sustainable development into account simultaneously, we decided to build scores reflecting the practices or performance leading to the sustainability of farms. This approach aims to apply the work of Briquel et al. (2001) who recommend a composite approach of indicators related to sustainable development. The construction of indicators is made possible using the database which incorporates several criteria involved in the definition of each pillar.

In order to account for the relationships between pillars of sustainability within supply chains, several methods have been used in the literature. Bloemhof et al. (2015), Galli et al. (2015) and Yakovleva (2007) list relevant indicators and propose an analysis grid. Matos and Hall (2007) adopt a life cycle assessment. Some authors propose statistical modelling: Mastronardi et al. (2015) use analysis of variance (ANOVA) and multivariate analysis of variance (MANOVA) while Hernandez et al. (2012) use factor analysis.

In addition to the presentation of descriptive statistics for each score and its components, a simultaneous equations model is developed on the basis of the scores calculated. Simultaneous equations models can be used if there are interactions between variables of interest (Aubert and Enjolras, 2016). In our case, there is a potential interaction between the economic, environmental and

social scores. This approach aims not only to identify the links between the three pillars of sustainability but also to consider the extent to which they interact. We can thus assess how the farmers' social, economic and environmental behaviour reflects a global farming rationale.

Beyond the presumed interdependence of the three pillars of sustainability, we consider that selling within SFSCs is a determinant of each score. In the model, SFSCs condition the farmers' behaviour. In order to validate the relevance of the model implemented and hence the interaction between scores, we have to test that the correlation between each error term is significantly different from zero (Berndt, 1991). Because we observed the existence of such a correlation between error terms, OLS estimates would be both biased and inconsistent. We therefore implemented Seemingly Unrelated Regression Equations in order to improve the efficiency of the estimates (Zellner, 1962).

Formally, the model tested takes the following form:

$$\left\{ \begin{array}{l} Score_{Economic} = \alpha_0 + \alpha_1 Score_{Environmental} + \alpha_2 Score_{Social} + \alpha_3 SFSC + \varepsilon_{Economic} \\ Score_{Environmental} = \beta_0 + \beta_1 Score_{Economic} + \beta_2 Score_{Social} + \beta_3 SFSC + \varepsilon_{Environmental} \\ Score_{Social} = \gamma_0 + \gamma_1 Score_{Economic} + \gamma_2 Score_{Environmental} + \gamma_3 SFSC + \varepsilon_{Social} \end{array} \right.$$

Where:

$\alpha_1, \alpha_2, \alpha_3$ are the coefficients associated with the equation of the economic score.

$\beta_1, \beta_2, \beta_3$ are the coefficients associated with the equation of the environmental score.

$\gamma_1, \gamma_2, \gamma_3$ are the coefficients associated with the equation of the social score.

$\varepsilon_1, \varepsilon_2, \varepsilon_3$ are the error terms associated with each of the equations.

4. Measurement and characterization of the different pillars of sustainability

The pillars of agricultural sustainability are a complex phenomenon to grasp since they do not refer to one single dimension, but to several ones. The data at our disposal allow us not only to obtain a representative overview of farms specializing in fruit production, but also to take into account the different dimensions of the pillars of sustainability simultaneously in order to understand them in the most comprehensive way possible. Starting from the variables associated with each pillar of sustainability, we build scores that reflect their multi-dimensionality.

Irrespective of the score considered, we assume that each one must be based on several indicators. The combination of these factors provides a better understanding of the three pillars considered (Lyytimäki and Rosenström, 2008; Niemeijer and de Groot, 2008a; Niemeijer and de Groot, 2008b). Because each indicator influences the conclusions obtained, all of them must be reproducible and defined in a transparent way (Dale and Beyeler, 2001; Niemeijer and de Groot, 2008a).

4.1 Economic sustainability

The economic sustainability of farms is defined on the basis of four indicators. Each of them reveals a characteristic of the farm or of its owner (Table 1a). The literature highlights the fact that economic

and financial factors such as profitability, liquidity and productivity contribute to farm sustainability (Latruffe et al., 2016). In our study, we focus more on production practices by assuming that the productive behaviour reflects not only the economic dimension but also the long-term implication of the farmer (Sabiha et al., 2016). Hence, the factors considered are the following: the fact that the farmer renews his orchards due to ageing or enlargement, the fact that he owns his land and the fact that he is insured. Each factor is defined in a dichotomous way. The value is set to 1 if the farmer validates the item and 0 if not.

Table 1a. Indicators relating to the definition of the economic score

Renewing orchards appears to be a revealing element of a farmer's vision for the future of his activity. However, not all farmers who have renewed their orchards over the past five years are motivated by the same reasons. Four reasons have been identified: fight against diseases, introduction of new varieties, ageing of the orchard and expansion of the farm. The last two items were selected as being indicative of a producer's confidence in the sustainability of his activity. The first two indicators of the score reflect these aspects.

In addition to these two indicators revealing the farmer's confidence in the sustainability of his activity, three objective indicators are taken into account. The fact that the farmer owns his cultivated land is also an indicator of sustainability (Hanson et al., 2008). The last indicator of economic sustainability is the fact that a farmer insures his crops, thereby providing him with protection against a drop in yields related to climatic hazards (Enjolras and Sentis, 2011).

Diversification leads to a greater economic sustainability of farms because it offers protection against climate and market risks (Bradshaw et al., 2004). Insofar as recorded farms all specialize in fruit production, they all dedicate at least 50% of their area to this type of production. Accordingly, an indicator of economic diversification is not explicitly taken into account.

The overall economic sustainability score takes a value between 0 and 4 according to whether the farm satisfies any or all of these criteria (Table 1b).

Table 1b. Characteristics of the economic sustainability score

On average, we find that farmers meet one of the criteria identified. This result is not surprising in that each criterion is validated by only a minority of farmers (Table 1a). More specifically, if we characterize farms according to their economic score, we note that the higher the score, the more farms have a relatively higher turnover, more debts and a larger workforce (Table 1c).

Furthermore, farms have a relatively high economic score if the farmer's spouse does not provide an additional source of income. In other words, the economic score seems to be higher when global revenues depend solely on the agricultural activity.

Table 1c. Characteristics of farms with regard to their economic score

4.2 Environmental sustainability

The environmental dimension of sustainability encompasses many aspects which can be measured through various complementary indicators. One of the most acknowledged is the reduction of

expenditure on chemical inputs (fertilizers and pesticides) through the use of substitutes, which can be considered at the farm level and reveal farmers' practices in favour of the environment (van der Werf and Petit, 2002; Braband et al., 2003; Bockstaller et al., 2011; Majewski, 2013; Sabiha et al., 2016). Soil management reduces the impact of human activities on biodiversity (Alkan Olsson et al., 2009; Lebacqz et al., 2013; Latruffe et al., 2016). Other indicators are considered, because of their direct impact in favour of the environment: careful management of water resources and the level of energy dependence. For each of these elements, various actions can be implemented. For example, grass protects soils, water tanks lead to savings on this input and the use of solar panels reduces energy dependence. The computed score is based on five environmentally-friendly actions reported as being implemented by farmers as part of their agricultural practices (Table 2a). For each of these actions, a dichotomous indicator has been defined showing whether the farmer claims to have implemented such an action (value equal to 1) or not (value equal to 0).

Table 2a. Indicators relating to the definition of the environmental score

While more than 70% of farmers claim to implement most of the actions, actions to offset energy dependence remain limited. Calculating the overall environmental sustainability score shows that most farmers claim to implement at least 3 of the actions identified, given that all of them apply at least one on their farm (Table 2b).

Table 2b. Characteristics of the environmental sustainability score

Considering the components of the environmental score (Table 2c), we find a coherence in the expected relations. Environmental scores are higher when the farm dedicates all or part of its activity to organic agriculture. Moreover, farmers who own the fewest sprayers are also those who score the highest.

Table 2c. Characteristics of farms with regard to their environmental score

4.3 Social sustainability

Social sustainability is a key issue for sustainable development. Some studies considered this dimension through the well-being of the farmer and his family. In such cases, the level of education, the working time or the total workforce are the main factors used to evaluate social sustainability (Lebacqz et al., 2013; Terrier et al., 2013; Latruffe et al., 2016). However, these criteria suffer from a certain degree of subjectivity while the economic and environmental dimensions are based on objective factors (Latruffe et al., 2016). Our study therefore focuses on criteria beyond the family circle, which consider the importance of local employment and the fact that the producers are organized to sell their production (Table 3a). Each of these indicators is defined in a dichotomous way. The value is set to 1 if the farmer has adopted a practice and 0 if not.

Table 3a. Indicators relating to the definition of the social score

Farmers work together or help each other at a rate of more than 70%, reflecting very intense social relations. However, farmers do not consider local employment to be a key criterion in the

search for social sustainability. The calculation of the social sustainability score shows that, on average, farmers implement one of these two criteria (table 3b).

Table 3b. Characteristics of the social sustainability score

Farms with the highest social score are those where total employment is relatively low in absolute value, but is more local (Table 3c). In addition, the social score is higher when farmers are recently installed on their farm, reflecting a desire for integration.

Table 3c. Characteristics of farms with regard to their social score

4.4 The pillars of sustainability with regard to selling via short food supply chains

Insofar as selling within SFSCs appears to help understand farm sustainability, we now consider how the scores calculated for each of the pillars differ depending on the chosen supply chain. The results suggest that fruit producers who sell through SFSCs are more likely to adopt social sustainability while they are less likely to adopt economic sustainability (Table 4).

Table 4. Selling through short food supply chains and sustainability scores

Selling through SFSCs thus appears to be a criterion of differentiation, as the farmers concerned are more sensitive to the social pillar than other farmers. They prefer to pool production with other farmers and hire more local employees. Another point of differentiation is the vision that producers have of economic sustainability. Farmers who do not sell within SFSCs favour this latter pillar of sustainability while it would appear to be of secondary importance for producers who sell within SFSCs.

The results also tend to emphasize that the choice of a supply chain does not affect their behaviour in terms of environmental sustainability. All farmers appear very concerned by environmental issues and they all adopt environmentally-friendly activities regardless of their preferred supply chain.

5. Interdependence of the pillars of sustainability, in connection with the supply chain

The results of the econometric model confirm the influence of the supply chain on the different scores calculated (Table 5). Fruit producers who sell within SFSCs are more sensitive to social issues than economic ones. As a matter of fact, SFSCs are associated with a larger and more skilled workforce (Mundler and Laughrea, 2016). Similarly, we confirm that environmental issues are seen as a challenge by all farmers, irrespective of their supply chain, with all of them feeling concerned by this pillar of agricultural sustainability.

Table 5. Interdependence of the pillars of sustainability

Taking the calculated scores into account simultaneously allows us to assess the importance of economic sustainability. This pillar assumes a dominant position insofar as it conditions the two other pillars and the latter in turn impact the level of the former. More specifically, the results show

that farmers who place economic considerations at the heart of their concerns are those who neglect the more social and environmental considerations. These last two pillars would therefore appear to be in opposition with the challenges of economic sustainability.

However, the environmental and social pillars can themselves be seen to be independent. Farmers who place social sustainability at the heart of their concerns are not necessarily those who attach the same degree of importance to environmental issues.

It is therefore clear that two pillars of sustainability (environmental and social) are independent while each of them interacts negatively with the economic sustainability of farms. The results obtained can be summarized as follows (Figure 1).

Figure 1. Interdependence of the pillars of sustainability

6. Conclusion

This article addressed the issue of sustainability in agriculture and more specifically the relationship between the adoption of short food supply chains (SFSCs) and the pillars of sustainable development. Indeed, SFSCs present several advantages in strengthening the sustainability of the farms concerned. Among these farms, we focused on fruit production, one of the most prominent French agricultural sectors in diversifying its supply chains, while largely adopting short food supply chains.

A database focused on fruit-producing farms was created on the basis of a double stratification: geographical location on the one hand and the physical size of farms on the other. This stratification allowed us to obtain data representative of French fruit-producing farms which are mainly located in 3 regions. Furthermore, the data enabled us to consider the different facets of the economic, environmental and social pillars of sustainability.

The multi-dimensionality associated with each pillar makes the analysis complex. In order to take these different aspects into account as far as possible, scores were calculated by combining different indicators. These scores incorporate the multiple facets of each pillar. Moreover, they allow us to take account of the interaction of the different pillars with one another which is conditioned by the type of supply chain. Thus, an econometric model with simultaneous equations was estimated, enabling us to assess and measure these interdependencies. Insofar as the type of supply chain determines each of the pillars of sustainability, the model specified and tested this possible relationship for each of the pillars.

The econometric model shows that the pillars of sustainability interact. More specifically, economic sustainability is opposed to both social and environmental sustainability. Furthermore, social and environmental sustainability do not appear to interact with one another. Farmers thus make a choice relating to their economic performance that appears opposed to their environmental and social performance. In this context, the manifestation of the three pillars of sustainable development does not, therefore, follow an overall rationale but rather a differentiated strategy. Furthermore, while selling through SFSCs translates into increased social sustainability, it also reflects more limited economic sustainability. Environmental sustainability seems to concern all farmers, in that the type of supply chain does not influence the level of environmental sustainability.

The results nevertheless appear to be conditioned by the size of the sample and the calculation of scores. Surveying additional farms would refine the extrapolation coefficients and thus the measurement of the different dimensions of sustainability. Moreover, expanding the number of

dimensions used to calculate the sustainability scores would lead to a more precise assessment of the complexity of each of the pillars considered.

This study therefore deserves to be expanded with regard to both the productive systems considered and the implications it raises. The observed interdependencies indeed highlight a problem in reconciling economic imperatives with social or environmental requirements. As a matter of fact, changes in supply chains are associated with organizational issues in order to combine production and marketing. Most farmers may not adopt SFSCs unless this conversion guarantees their level of activity without adding excessive risk. Public policies should pay particular attention to this situation to ensure greater complementarity of the pillars of sustainable development, especially by promoting a greater diversification of supply chains.

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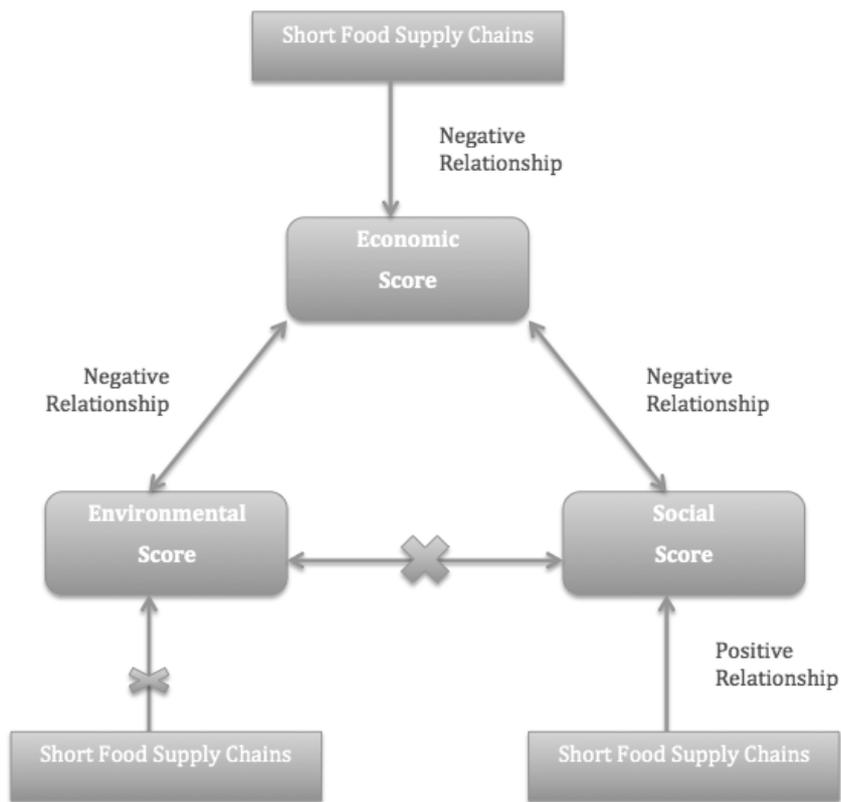
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Figure 1. Interdependence of the pillars of sustainability



Single arrows denote unilateral causality, double arrows denote bilateral causality while crosses denote a lack of causality.

Table 1a. Indicators relating to the definition of the economic score

	Proportion of farms that validate this criterion
Farmers renew their orchards due to ageing	16.45%
Farmers renew their orchards to enlarge	8.31%
Farmers are the owners of all the farmed land	33.49%
Farmers insured their crops in 2013	25.18%

Table 1b. Characteristics of the economic sustainability score

	Economic score
Mean	0.83
Standard deviation	3.71
Minimum	0.00
Maximum	4.00

Table 1c. Characteristics of farms with regard to their economic score

	Economic score
Turnover in 2013	0.2002**
Proportion of debts in the turnover	0.1662*
Total AWU	0.2208***

Whatever the test considered, H_0 : there is no correlation between the economic score for the variable considered versus H_1 : there is a significant correlation at the 1% (***), 5% (**) and 10% (*) thresholds.

	Economic score			
	Mean		Std deviation	
	Mean	Equality of means	Std deviation	Equality of std deviation
Main activity				
Farmer	0.85		3.67	
Other	0.62		4.41	
Secondary activity				
No	0.86		3.68	
Yes	0.72		3.96	
The spouse has an activity outside the farm				
No	1.17	***	3.53	
Yes	0.78		3.68	
The farm benefits from another source of income				
No	0.80		3.75	
Yes	1.00		3.47	

Whatever the test considered, H_0 : there is no difference in terms of means (or standard deviation) for the variable considered versus H_1 : there is a significant difference at the 1% (***), 5% (**) and 10% (*) thresholds.

Table 2a. Indicators relating to the definition of the environmental score

	Proportion of farms that validate this criterion
Fertilizer reduction	73.23 %
Pesticide reduction	82.12 %
Soil protection	86.40 %
Water management	74.46 %
Energy dependence	16.29 %

Table 2b. Characteristics of the environmental sustainability score

	Environmental score
Mean	3.32
Standard deviation	5.08
Minimum	1.00
Maximum	5.00

Table 2c. Characteristics of farms with regard to their environmental score

	Environmental score
Proportion of organic farming area	0.1672**
Number of treatments / ha	0.1006
Number of sprayers	-0.1408*
Mean age of sprayers	0.2453***

Whatever the test considered, H_0 : there is no correlation between the environmental score for the variable considered versus H_1 : there is a significant correlation at the 1% (***), 5% (**) and 10% (*) thresholds.

		Environmental score			
		Mean		Std deviation	
	Mean	Equality of means	Std deviation	Equality of std deviation	
Organic farming certification					
No	3.17	***	5.00		
Yes	3.63		4.92		
GlobalGap certification					
No	3.27		5.16		
Yes	3.54		4.77		
Product Conformity Certificate (CCP)					
No	3.33		5.18	***	
Yes	3.18		1.70		
The PO implements requirements specification					
No	3.30		5.42	*	
Yes	3.37		4.51		
The PO defines active substances to be used					
No	3.32		5.12		
Yes	3.34		5.04		
The PO defines a list of forbidden products					
No	3.28		5.28		
Yes	3.48		4.57		
The PO establishes a treatment schedule					
No	3.29		5.17		
Yes	3.43		4.83		

Whatever the test considered, H_0 : there is no difference in terms of means (or standard deviation) for the variable considered versus H_1 : there is a significant difference at the 1% (***), 5% (**) and 10% (*) thresholds.

Table 3a. Indicators relating to the definition of the social score

	Proportion of farms that validate this criterion
Production pooling	71.58%
'Local' jobs	23.41%

Table 3b. Characteristics of the social sustainability score

	Social score
Mean	0.95
Standard deviation	3.21
Minimum	0.00
Maximum	2.00

Table 3c. Characteristics of farms with regard to their social score

	Social score
Total AWU	-0.0914**
Proportion of 'local' jobs	0.6956
Age of the farm owner	0.0138***
Time since installation	-0.1560***

Whatever the test considered, H_0 : there is no correlation between the social score for the variable considered versus H_1 : there is a significant correlation at the 1% (***) , 5% (**) and 10% (*) thresholds.

Social score				
Mean		Std deviation		
Mean	Equality of means	Std deviation	Equality of std deviation	
Member of a producer organization				
No	1.07	***	3.01	***
Yes	0.75		3.26	

Whatever the test considered, H_0 : there is no difference in terms of means (or standard deviation) for the variable considered versus H_1 : there is a significant difference at the 1% (***) , 5% (**) and 10% (*) thresholds.

Table 4. Selling through short food supply chains and sustainability scores

Selling through short food supply chains			
	No	Yes	Statistical test
Social score			
Mean	0.64	1.17	***
Standard deviation	2.70	3.14	
Economic score			
Mean	1.05	0.68	***
Standard deviation	3.87	3.33	
Environmental score			
Mean	3.34	3.32	
Standard deviation	4.68	5.47	

Whatever the test considered, H_0 : there is no difference in terms of means or standard deviation for the variable considered, versus H_1 : there is a significant difference at the 1% (***), 5% (**) and 10% (*) thresholds.

Table 5. Interdependence of the pillars of sustainability

	Estimated parameters	Standard deviation	T-test	Estimated parameters	Standard deviation	T-test	Estimated parameters	Standard deviation	T-test
	<i>Social score</i>			<i>Economic score</i>			<i>Environmental score</i>		
Constant	0.89***	0.20	4.29	2.82***	0.21	13.73	3.91***	0.28	13.90
Economic score	-0.12**	0.06	-2.20				0.19	0.14	1.43
Environmental score	0.05	0.04	1.43	-0.18***	0.05	-3.39			
Social score				-0.21**	0.09	-2.20	-0.36***	0.11	-3.39
Selling through short food supply chains	0.35***	0.09	3.98	-0.29**	0.11	-2.51	-0.23	0.17	-1.40
<i>Number of observations</i>	175			175			175		
<i>Fisher test</i>	8.04			5.47			1.36		

Asterisks denote statistical significance at the 1% (***), 5% (**) and 10% (*) thresholds.