Analysis of the presence of an organic farmland premium price

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Abstract

The European "Green Deal" sets a goal of 25% of land in organic agriculture by 2030, compared to currently 8.5%. However, the transition to organic agriculture is not encouraged because it does not generate additional income for farmers. This lack of monetary incentive slows the conversion dynamics of farmers in France.

In order to solve this problem, we are looking to identify other sources of income allowed by organic farming. We are assuming here the existence of a "premium" for organic farmland (organic land would be sold at higher prices than conventional land), allowing the farmer to realize a capital gain. The existence of this premium is justified as the payment for the relatively more numerous ecological services on conventional land (reduction of erosion, improvement of soil water storage capacity, etc.). In this study, we compare the sales prices of 189,000 lands sold between 2017 and 2020 (16,349 of which are organic). The results, based on an OLS regression controlling for Ricardian rent and the determinants of residential rent, show that organic land is sold at a lower price than conventional land. To check the robustness of the effect, we perform two types of matching, the first based on a *Propensity Score Matching* and the second by minimising the geographical distance. The results show that organic land is sold at a lower price (3% less, i.e. around 200€ per hectare) than the same conventional land. This can be explained by a spatial mismatch between the supply and demand of organic land. If an organic farmer wants to buy farmland, he will have a conventional opportunity about 3km from his farm compared to 6.3km for an organic opportunity. This average difference of 3km allows us to understand the non-difference in prices between the two types of land.

Keywords: `Farmland price, Organic farming, Farmland market`

`JEL classification: C23, Q15, R14`

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1. Introduction

The growth of organic farming in France has been significant since the 2010s, coinciding with a significant increase in demand for organic products. The expansion of organic supply can be achieved in two distinct ways: the conversion of land from conventional to organic farming or the acquisition of pre-existing organic land, allowing immediate organic production. In the first case, the process of converting agricultural land to organic farming usually takes 2-3 years. Therefore, it is reasonable to expect that land for immediate organic production will have a higher market value. Moreover, given the scarcity of such land, which currently represents only 10% of all agricultural land in France, its limited availability in the face of sustained demand should lead to an increase in its price.

According to Muller et al. (2017), organic farming (OF) is agriculture that allows it to respond to demographic challenges, i.e. to feed 9 billion people by 2050 while respecting the environment. More precisely, according to Barbieri et al. (2021), due to the availability of natural nitrogen, organic farming can reach 60% of the world's agricultural land. Another issue brought about by this full OF is the land occupation which will increase due to the lower yield in OF between 8 and 25%. Thus Muller et al. (2017), depending on the scenario, based on a change of diet (less animal protein), they estimate that the occupation of agricultural land will have to increase by at least 6 %. However, this issue has yet to arise. According to Helga et al. (2021), only 1.5% of the world's surface area was cultivated organically in 2019. At the European level, the objective of the European Green Deal is to reach a quarter of the organic surface area by 2030, compared to 8.5% in 2020. For Latruffe et al. (2013), the main obstacle to the conversion of farmers is the financial constraint, the fear of losing income compared to the conventional situation. It is, therefore, interesting to see if the fears of conventional farmers are well founded. Moreover, in France, the economic situation of organic farmers is not better than that of conventional farmers. Indeed, according to Veron (2023)(Appendix.1), there is no difference in income between organic and conventional farmers. From the Farm Accounting Data Network data over the period 2004-2019, we find that even though organic farmers have 18% lower total costs (reduced purchase of fertilisers and pesticides) and higher subsidies received, the farming practice does not improve the Gross Operating Surplus.

In order to convince a part of the farmers who are hesitant to convert for economic reasons, it is essential to find other potential sources of income heterogeneity linked to the conversion to OF. Here we will focus on the agricultural land market in France. To answer the question: Does organic farming increase the value of land? Is there a premium price for organic farmland? Therefore, we propose observing the differences in sales prices that may exist depending on the practices.

The hypothesis of the presence of an organic farmland premium price comes from the fact that the environmental quality of OF land is better than that of conventional land. The high quality of land used in OF is mainly due to three practices: crop rotation, permanent cover and fertilization with compost and green manure. According to Tuck et al. (2014), Underwood et al. (2011), land cultivated under OF has 30% more biodiversity than land cultivated under CF. On the one hand, this result can be explained by a more important environmental landscape (hedges and other semi-natural elements) in the organic land, allowing habitat development for different species. Furthermore, on the other hand, according to Geiger et al. (2010), CF using intensive insecticides and fungicides reduces the quantity of biodiversity. The obligation of permanent soil cover in OF makes it possible to improve carbon storage capacity (Gattinger et al., 2012) but also reduces soil erosion (Reganold et al., 1987). Finally, for Sautereau and Benoit (2016), Lotter et al. (2003), organic land has a higher capacity to store water, allowing better yields for organic surfaces during drought. Thus, organic land has intrinsically superior agronomic qualities to conventional land. It is interesting to see whether organic land sells for a higher price. In other words, do buyers of agricultural land value its environmental assets?

According to French Ministry of Agriculture (2022), in 2020, 51% of farms in France will be managed by at least one farmer over 55. This fact indicates that in the next few years, there will be many retirements; thus, much farmland will be available. This rent is often forgotten in profitability calculations. However, there is an organic farmland premium price. In that case, these farmers will have an interest in converting their land before selling it to realise a more significant capital gain and thus leave with a greater starting capital for retirement.

In this study, we will focus on the case of French agriculture, the country for which the challenges of OF are the most important in the EU. The European Union is the world's most considerable agricultural power with an estimated production of €418 billion in 2019[2], thanks in particular to France, the leading contributor with 18.55%. Nevertheless, among the top 4 European agricultural-producing countries, France has the lowest organic land ratio (7.5% in 2018 against 15.5% for Italy and nearly 10% for Germany and Spain). Thus, it is in France that the potential for conversion is the greatest. Another interesting fact is that France is the country in the EU-15 with the lowest average price for agricultural land. Indeed, in 2019, according to Eurostat (2021), agricultural land sold at an average price of 6000€ compared to 69600€ in the Netherlands. According to Ballet (2021), in 30 years, 7.7% of agricultural land has been artificialized. This decreased available land, coupled with a growing population and demand for environmentally friendly agricultural products, will result in increased land competition. This competition for agricultural land should lead to higher land prices. Thus it is interesting to observe the current state of the French agricultural land market. By studying the French agricultural land market, we can see the availability of organic and conventional land and their respective prices.

According to Rosen (1974), the price of a property can be decomposed by a set of characteristics that influence the price of that property; this is the hedonic pricing method. In the case of agricultural land, we separate the factors from the Ricardian theory of agricultural rent and the factors from the residential rent theory. The first type of factor refers to Ricardo's theory (Ricardo, 1817), which says that the value of land equals its productivity. Moreover, the residential factors refer to the value of agricultural land on the day

[2]Eurostat press release 14/09/2019

it is sold for residential use (Cavailhès and Wavresky, 2003). The hedonic price method has shown that the geographical location of agricultural land influences its price, particularly through its proximity to urban centers (Cavailhès and Wavresky, 2003). Other articles have shown that providing recreational services on agricultural lands, such as hunting, increases the price of this land (Henderson and Moore, 2006). Baldoni et al. (2021), Kilian et al. (2008), demonstrate that aids from the Common Agricultural Policy influence land prices. However, the influence of these aids on prices will depend on the constraint associated with their allocation. Indeed, coupled aids tend to increase the price of land, as the acquisition of land will almost automatically allow for increased production, thus increasing the coupled aids for production. Conversely, according to these authors, aids tied to agri-environmental measures will negatively impact the price of land, and this for two reasons. The first reason is that the new owner will not automatically receive the aids if they do not maintain the same agronomic practices. The second reason is that agri-environmental schemes are mostly located in regions where the soil or soil characteristics are poor or strongly constrain agricultural practices. Thus, the presence of agri-environmental subsidies on a plot of land can be synonymous with agronomic constraints for the future acquirer, thereby prompting them to reduce their purchase offer. Despite this, the link between the improvement of the ecological state of the land, allowed by the OF, and its sale price, has been little treated. The difference in the value of agricultural land between organic and conventional farmers is only addressed in the article of Fuller et al. (2021) with a study on the United States. This study found that in the United States between 2003 and 2011, organic farmland rents for 26% more than conventional land. In this paper, this premium seems unjustified because the organic situation does not improve the economic situation of farmers. This premium is equivalent to the willingness of farmers to pay to avoid going through 3 years of conversion. In this study, soil productivity is binary, so we can question the econometric strategy that does not allow for the omitted variables.

We will test the existence of a premium price for organic farmland using an original database of 188,827 farmland sales (of which 15,647 are organic farmers) carried out in France between 2017 and 2020. In order to isolate the marginal effect of organic practice on the price of land, we will control for other determinants already found in the literature (Ricardian rent and residential rent). First, an OLS regression will allow us to observe the influence of the Ricardian rent as well as the residential rent on the formation of the land price. Secondly, in order to make the distribution of the treatment (the organic practice) random, we perform a propensity score matching based on the land characteristic can influence the organic practice. After that, each organic land is matched with the most similar conventional land. Then, the price of the land, is compared to observe the influence of the organic practice on the price.

2. Determinants of agricultural land prices

Here we will present the main determinants explaining the differences in farmland prices.

For Cavailhès and Wavresky (2003), the price of agricultural land is equivalent to capitalising its future rents. These future rents can be of two kinds, agricultural rents (the income from the cultivated land) and residential land rent. The latter refers to the parcel's value if it is sold for residential use. According to Levesque (2007), this residential rent is 10 to 50 times higher than the sale price for agricultural use in France. Two cases are possible: the farmer anticipates that his land can never be converted to residential use (for example, too isolated from a town), where the price will depend solely on future agricultural rents. If they anticipate converting the land to residential use in the future, then the sale price will depend on the productive and geographical characteristics of the land.

2.1. Ricardian rent

First of all, let us look at the determinants of Ricardian rent and, more precisely, at the impact of soil and weather conditions on yields. For Ricardo (1817), the value of land depends on its capacity to produce. Thus, several factors will impact the productivity and, therefore, the value of land, the weather, and the properties of the soil, whether physical (slope, altitude, subject to erosion) or chemical (nitrogen and carbon content, Etc.), as well as the type of farming (mechanical work, chemical fertilization).

Currently, and in response to current environmental issues, the impact of weather conditions on agricultural production is the subject of significant research. It was in particular Mendelsohn et al. (1994) who first studied the impact of global warming on agricultural production. They found that the increase in temperature will lead to changes in crops. Indeed, at a given temperature, yields depend on the type of crop chosen, so plants that prefer temperate climates will be replaced by plants with high yields during warm periods [3]. This increase in temperature thus forces farmers to choose crops that are less and less profitable, explaining the negative relationship between temperature and revenue, and thus the Ricardian rent.

Also, Passel et al. (2017) obtains, in an analysis of European farms, that according to the different scenarios [4], the farms of Southern Europe will suffer more from global warming. Indeed, this generalized increase in temperature will benefit the northern European regions, increasing their production. In contrast, the southern regions, which are already warmer, will see their production decrease. Indeed, as the relationship between agricultural production and temperature is reversed U-shaped, the northern countries converge towards the maximum production, while the southern countries are on the other side of the curve and moving away from the maximum production. It is also essential to see the seasonal impact of this temperature rise, as warming in spring and autumn positively impacts agricultural production (allowing an increase in the harvest period). However, this warming harms production in winter and summer (in winter, the cold limits the proliferation of diseases and crop pests, and during relatively cold summers, the probability of drought is low). Concerning precipitation, according to the scenarios of IPCC (2000), this should increase, allowing a marginal increase in production by avoiding mainly the periods of drought. Nevertheless, its increase during

[3] In the article by Mendelsohn et al. (1994), they give the example of wheat, which is replaced by maize and then by pasture as the temperature increases

[4] The article simulates three climate scenarios for the year 2100 based on the IPCC (2000)report.

spring and autumn slows down the growth of the crops (the plants need sun during this period).

Soil composition will also impact yields. The productivity of the soil is mainly caused by the share of sand and the share of clay. Firstly, sandy soils decrease yields. Indeed, the high permeability of sandy soils makes water retention difficult and increases the loss of organic matter. It also appears that these soils are relatively more acidic than other soils, about 5.5Ph (Usowicz and Lipiec, 2017, Rusinamhodzi et al., 2011). While the clayey soils them, they have a better permeability allowing them to retain water and keep the nutritive elements.Panagos et al. (2012), from an index based on the rate of clay and sand of soils, produces a European map of soils according to their productivity. In the project European soil data center (Panagos et al., 2012), a map of slopes by geographical area is also available. This physical property of the soil also influences the productivity of the land. Indeed, sloping farmland is relatively more subjected to the critical erosive phenomenon. Indeed, the slope increases water erosion which can be accentuated by important mechanical work of the ground (deep ploughing, use of a tractor). Thus for several authors (Kiflu and Beyene, 2013, Gregorich, 1998), these phenomena lead to differences in the concentration of nutrients and carbon between the high and low part of the slope. These deficits in chemical elements can lead to a decrease in the productivity of the land.

The type of farming can also impact yields. Indeed, OF prohibits the use of chemical inputs. The differences in yields between the two types of agriculture, the average yield is between 20% (Seufert et al., 2012) and 9% (Ponisio et al., 2015). These meta-analyses show that at the crop level, the results are different. Indeed, while orchard crops have a low yield decrease, cereal yields decrease by more than 20%. It is, therefore, essential to control the type of crop grown on the farmland.

2.2. Residential rent

The value of the residential rent corresponds to the anticipated value of the land on the day it is converted to residential use. According to Cavailhès et al. (2011), the sale price of agricultural land is equal to:

$$P = \underbrace{\frac{R_A}{i}(1 - e^{-it^*})}_{\text{Ricardian rent}} + \underbrace{\Big(\frac{R_0 - \delta x}{i} + \frac{g}{t^2})e^{-it^*}}_{\text{Residential rent}} \tag{1}$$

Where R_A denotes the agricultural rent, R_0 denotes the residential rent in the Central Business District (CBD), x the distance of the land from the CBD multiplied by δ the unit transport cost, g the population growth rate, i the discount rate and t^* the date of conversion to residential use. So if we decompose the second part of the equation, we see that the residential rent depends on three parameters: the population growth rate, the distance to the central business district and the conversion date to residential use.

Firstly, an increase in the anticipated demographic growth of the area where the land is located leads to an increase in future demand. This increase in demand leads to a rise in the residential rent on the day when the conversion is possible. Thus, as the population growth of dynamic cities is higher than that of isolated municipalities, a negative relationship between residential rent and distance from the CBD can be observed.

Nevertheless, this relationship is not linear, as shown in Cavailhès et al. (2011), there is a *village effect*. Thus, as we will show in our data (fig.1), the smaller towns also attract populations. Indeed, agricultural land in cities with more than 1500 jobs is sold at a higher price than land in the suburbs of larger cities (more than 5000 jobs). This attraction is smaller than that of the large cities (the *CBD* in eq.1), but by attracting jobs, they also create demand for housing and allow an increase in land prices.

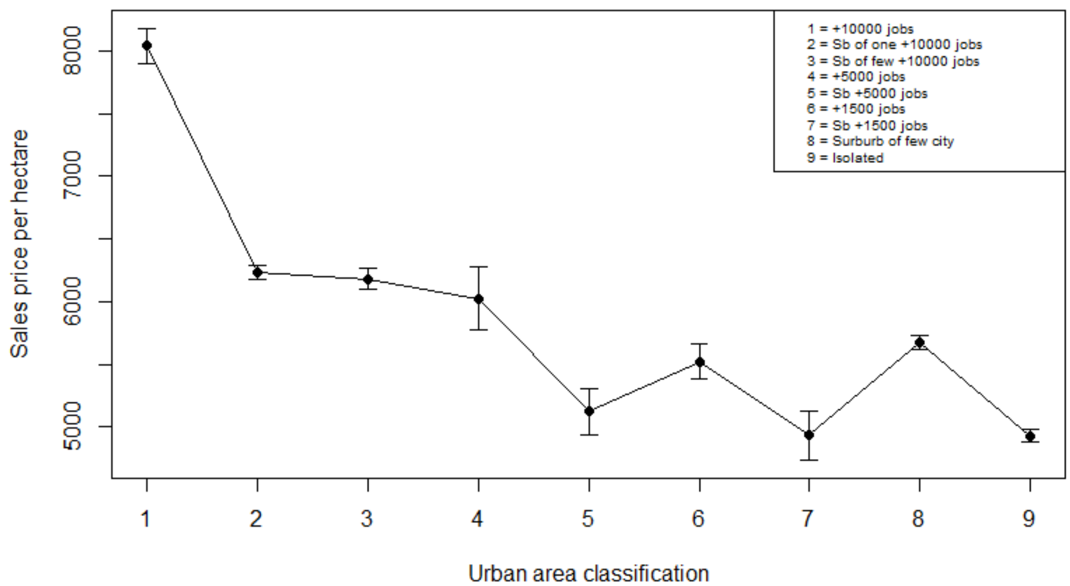

Figure 1: Average price of sales per urban classification a confidence interval of 99.9%

The second factor influencing land value is the distance to the CBD boundary. When a city is dynamic, its population growth is significant, and thus the urban planning authorities may decide to expand the city, i.e. to push the residential boundary. Thus, if agricultural land is located on the border of a dynamic city, the probability that the planning authorities will make this land buildable is high.

Thus, it seems relevant to first observe the importance of the two types of value in setting the price, i.e. whether the land is bought for its physical, pedological and climatic properties, ensuring important future agricultural production. Or if the land is bought for its geographical characteristics. That is, the buyer wishes to capitalize on the future residential rents of this land. Secondly, as OF impacts the Ricardian rent, the study will examine the price differences that may exist between conventional and organic farmland markets.

3. Methodology and data: Land valuation

3.1. Data: Request for Land Value and Graphical Land Register

In order to answer our issue, we should create an original database. Indeed in France, the organic character of the land at the time of the sale is not specified. This database could be built from two existing databases, *Demand for land value* and the *Graphic land register*.

The first database, *Demand for land value*[5], lists all land transactions (sale of houses, buildings or agricultural plots) carried out in France over the last five years (excluding the 4 French departments Moselle, Bas Rhin, Haut Rhin and Mayotte). It is produced by the French General Direction of Public Finances and includes for each transaction the sale price (excluding notary fees), the surface and the GPS coordinates of the land. The second database, the *Graphical Land Register*, annually refers to all the agricultural land receiving CAP aid. The French Service and Payment Agency produce it. This database allows us to know the GPS position of each field as well as their size and crop. Since 2015, it has been possible to know the agricultural practice of each parcel (OF or CF).

(a) (b) (c)

Figure 2: Land database construction (a) Request for Land Value (b) Graphical Land Register (c) Merging between (a) and (b)

[5]This database, called *Demande de valeur foncière* in French, is open access and available at the following address: https://app.dvf.etalab.gouv.fr/

To create this database, from the *Demand for land value* database, we extracted, for each year, all sales of agricultural land without building (fig.2.a). In a second step, we extract the layer of each year from the *Graphical Land Register* database (fig2.b). Then the two layers of the same year are merged by geographical position, and we keep only the merged parcels (fig2.c). In our fictive example[6](fig2), from the three land sales, we obtained two observations, i.e. we know the selling price per hectare of these two conventional lands. Then we apply the clean data methodology adopted by the *SAFER* [7], consisting of removing sales involving areas of less than 0.7 hectares and removing outliers [8].

In order to verify the accuracy of the fusion of the two layers, we introduce a new test to ensure that the sold land is correctly associated with the correct parcel. To do this, we add the landowner from period t-1 and period t+1. Once done, we only keep the lands for which the operator's identification number in the year prior to the sale (t-1) is different from the identification number in year t+1. We only retain the sold parcels that have actually changed ownership. Finally, we have 188827 observations (173180 conventional and 15647 organic sales) between 2017 and 2020.

3.2. Hedonic regression

To identify the impact of OF, it is necessary to regress the price of the plot according to the agricultural practice as well as to control for the Ricardian and the residual rent, as follows::

$$Y_i = \beta_0 + \beta_1 ORG_i + \beta_2 Ricardian_i + \beta_3 Residential_i + \epsilon_i \tag{2}$$

This OLS model will make it possible to identify the presence of added value associated with the OF practice and observe the determining variables in land sale price. The Ricardian rent will be captured here by the following variables, the seasonal average temperature and the sum of seasonal rainfall. But also the properties of the land (size, slope and composition) as well as the dominant crops. The INSEE classification of the municipalities will approximate the residential rent according to the level of available employment[9], population growth and the rate of artificialisation.

[6]The agricultural practice of the plots, in fig2.b, is randomly assigned

[7]*Société d'aménagement foncier et d'établissement rural* is an organisation in charge of the orientation of agricultural land. They are in charge of ensuring the proper functioning of the agricultural land market and preserving agricultural areas. They also publish an annual report, which includes the average prices of agricultural land at the sub-departmental level.

[8]Removal outlier *SAFER* methodology:

$$|x - me(x)| < 1.5 * (Quartile_3(x) - Quartile_1(x))$$
$$\text{with } x = ln(\frac{Price}{ha}) \text{ and } me(x) = \text{median}$$

[9]Classification developed by INSEE, classifying French towns according to the number of jobs available (more than 10,000 jobs, more than 5,000 jobs, more than 1,500 jobs)

3.3. Propensity Score Matching

The decision to convert to organic farming depends on geographic and climatic characteristics external to the individual's decision. Therefore, it is necessary to control for these variables. Matching can help account for these omitted variables and correct for selection bias. Thus, we will compare two fields with the same probability of being used for organic farming.

According to a study by Allaire et al. (2015), in France, organic farmers are distributed very heterogeneously across the territory (*Var, Haute-Alpes* and *Bouches du Rhône* with more than 40% of the land farmed organically compared to less than 2% for *Pas-de Calais, Somme* and *Val d'Oise*). This initial concentration of organic farmers positively influences their future development. Additionally, in the same article, it is found that areas with low to moderate slopes (foothills and medium mountains) have a higher concentration of organic farming practices. Another study by Schmidtner et al. (2012) conducted in Germany indicates that organic farmers are concentrated in areas with lower soil quality and less favorable climatic conditions, based on the soil climate index provided by the German Federal Office for Building and Regional Planning in 2002. Furthermore, they also tend to be located in regions with higher rainfall.

The table 3 gives the result of the logistic regression model determining the probability for agricultural land to be operated in an organic manner. Based on these results, we can define propensity scores (Rosenbaum and Rubin, 1983) corresponding to the probability of parcel i being operated organically given its set of characteristics $X = x_i$. Thus, the propensity score can be denoted as $p(X) \equiv Pr(P = 1|X = x_i)$.

As $p(x)$ is continuous, the probability of two observations having the same propensity score is therefore zero. Hence, it is necessary to apply a matching method based on $p(x)$, specifically the matching algorithm. To achieve this, we employ the *Nearest Neighbor Matching* method (Stuart, 2010), which involves minimizing the distance between propensity scores in the treated group and the control group. Each treated observation is matched with the observation having the closest propensity score. To compare different specifications of the matching algorithm, we introduce a *caliper*, refer to a predetermined maximum allowable distance that can separate a treated individual from an untreated individual.

4. Empirical analysis

4.1. First Analysis

Table 1 indicates that the number of transactions is relatively stable over the period but that the relative share of organic sales is increasing. According to agricultural practice, the map 3, represents the average price per hectare by the department between 2017 and 2020. This map shows that the distribution of prices on the territory varies a little between organic and conventional practices. It can be seen that land in the middle part of France is the least expensive, whereas land on the Mediterranean coast is expensive.

If we compare the data in our database with the average price of free land sales in 2020 produced by the

	2017	2018	2019	2020
Conventional sales	92.9%	92.4%	91%	89.9%
Organic sales	6.3%	7.1%	9%	10.1%
Total sales	48904	49931	50818	43682

Table 1: Distribution of data by practice and year of sale

SAFER[10], there is no significant difference between the two series (student test at a risk threshold of 0.1%). The average price of the SAFER database is 6414 euros per hectare compared to 6389 euros per hectare in our database.

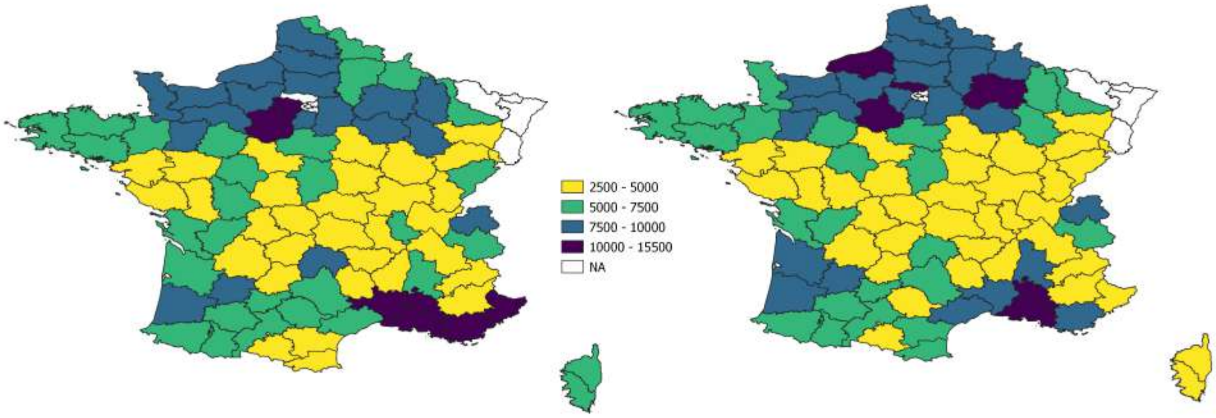

Figure 3: Average price per hectare per department over the period 2017-20 (in OF on the left, in OC on the right)

4.2. Comparison of land valuation: presence of farmland organic premium price?

Using the original database containing the 188827 agricultural land transactions carried out in France between 2017 and 2020, we will observe the predominant factors in land prices.

The specification on the table 2 shows the results obtained by the OLS regression of the price per hectare of land sold as a function of the land characteristics relating to Ricardian rent (agricultural practice, slope, weather and soil characteristics) and relating to the geographical positioning of the plot, which makes it possible to approximate the residential rent (demographic growth, urbanisation rate).

Based on these specifications, it appears, over the period 2017-2020, that the organic character of land negatively influences the price of the land. Indeed, from specifications 1 to 3, we observe that organic land sells less than conventional land.

Concerning the Ricardian rent, soils with a fine composition (high clay content), allowing better water storage and nutrients sell 13% more than coarse soils (high sand content). Farmland in flat areas sells 7%

[10]From the average DVF database by region and department every year, not distinguishing by agricultural practice available on the site:https://www.le-prix-des-terres.fr/

more than sloping land. The influence of seasonal rainfall shows that a 1% increase in summer and winter increases the price by 0.4% and 0.2%, respectively. In contrast, the same increase in autumn or spring decreases the price by 0.4%. The results validate the importance of Ricardian rent in land prices. Therefore, the determinants of soil productivity influence an important part of the price of land.

It can also be noted that the average summer temperature, according to the specifications, has an positive impact on the selling price of land. This result is interesting because it shows that residential rent has a more significant impact than Ricardian rent. Indeed, on the one hand, according to Mendelsohn et al. (1994), Passel et al. (2017), yields are lower during warm summers. Furthermore, on the other hand, according to Grout et al. (2016), housing prices increase by 7.2% when the average temperature in July increases by 2°C. The coefficient of the summer temperature thus indicates that the marginal increase in residential rent are higher than the loss of yield due to high temperatures.

The spatial dynamics surrounding agricultural land also influence the price of land. We observe that the price of land evolves positively with demographic growth and the rate of artificialization. Indeed, these two elements increase the residential demand in the area and increase the probability of agricultural land being sold for residential use. This finding is confirmed by the result, that land prices tend to be higher when the land is situated in larger municipalities and closer to the town hall (a proxy for proximity to the city center).

4.3. Robustness check: Matching organic/conventional land

In this second part of the analysis, we aim to verify the robustness of the effect obtained in Table 2, which is the negative influence of organic farming on land sale prices. To achieve this, we will compare the sales prices pairwise for land parcels with an equal probability of being cultivated. In order to make the treatment randomly distributed, we assign to each treated observation (sold in OF at the time of sale) the control observation with the characteristics closest to the treated individual. We will carry out two different matching operations. The first matching will be done by minimising the Propensity Score derived from the probability of being treated in organic farming with respect to the observable characteristics. The second matching will be done by minimising the geographical distance to the plots sold in the same year. In this way, each treated observation will be matched with the closest conventional plot geographically sold in the same year..

Propensity score matching

This pairing is based on the propensity score derived from the logistic regression results, as provided in Table 3. The results from the table confirm that soil characteristics influence the adoption of organic farming. Specifically, sloping lands are more likely to be cultivated using organic practices. Similarly, lands receiving higher rainfall in winter and lower rainfall in spring are also more likely to be used for organic agriculture.

From the propensity score of each observation, we applied two distinct matching algorithms. The first

	2017-2020		
	(1)	(2)	(3)
Organic	-0.02**	0.002	-0.02**
Area (10ha)	0.04***	0.04***	0.04***
Area (10ha)^2	-0.00***	-0.00***	-0.00***
Texture (ref: Coarse)			
Medium	0.08***	0.08***	0.08***
Medium Fine	0.12***	0.12***	0.12***
Fine	0.14***	0.13***	0.13***
Slope (ref: Level)			
Sloping	-0.07***	-0.07***	-0.07***
Moderately steep	0.04***	0.03***	-0.03***
Mean Temperature per season			
Summer	0.15***	0.15***	0.15***
Winter	0.13***	0.13***	0.13***
Autumn	-0.14***	-0.14***	-0.14***
Spring	-0.12***	-0.12***	-0.12***
Sum Rainfall per season (/100ml)			
Summer	0.38***	0.38***	0.38***
Winter	0.22***	0.22***	0.22***
Autumn	-0.34***	-0.34***	-0.34***
Spring	-0.35***	-0.35***	-0.35***
Urban class (ref:City of +10000 jobs)			
Sb one 10000 jobs	-0.09***	-0.09***	-0.09***
Sb of some 10000 jobs	-0.13***	-0.13***	-0.13***
City of +5000 jobs	-0.06***	-0.06***	-0.06***
Sb one 5000 jobs	-0.25***	-0.25***	-0.25***
City of +1500 jobs	-0.11***	-0.11***	-0.11***
Sb one 1500 jobs	-0.12***	-0.12***	-0.12***
Sb of some city	-0.13***	-0.13***	-0.13***
Isolated city	-0.15***	-0.15***	-0.15***
Year (ref: 2017)			
2018	0.04***	0.04***	0.04***
2019	0.05***	0.05***	0.05***
2020	0.08***	0.08***	0.08***
Year *Org(ref: 2017)			
2018		-0,03.	-0.02
2019		-0.04*	-0.02
2020		-0.003	0.01
Distance City hall(km)	-0.01***	-0.01***	-0.01***
(Intercept)	7.69***	7.7***	7.7***
Dept	TRUE	TRUE	TRUE
Crops Gr	TRUE	TRUE	TRUE
Bio*Dept	FALSE	FALSE	TRUE
Adj R^2	0.29	0.29	0.29
Num.obs.	184319	184319	184319

$^{***}p < 0.001$; $^{**}p < 0.01$; $^{*}p < 0.05$

Table 2: Farmland price decomposition, OLS regression

	Logit (Organic=1)
Year (ref: 2017)	
2018	0.12***
2019	0.39***
2020	0.53***
Texture (ref: Coarse)	
Medium	-0.13***
Medium Fine	0
Fine	0.12***
Slope (ref: Level)	
Sloping	0.10***
Moderately steep	0.13**
Mean Temperature per season	
Summer	0
Winter	0.27·
Autumn	-0.24
Spring	-0
Sum Rainfall per season (/100ml)	
Summer	-0.15
Winter	0.54**
Autumn	-0.1
Spring	-0.66***
Urban class (ref:City of +10000 jobs)	
Sb one 10000 jobs	-0.1*
Sb of some 10000 jobs	0
City of +5000 jobs	0
Sb one 5000 jobs	0
City of +1500 jobs	-0.1·
Sb one 1500 jobs	-0.3**
Sb of some city	-0.15**
Isolated city	-0.04
Departement	TRUE
Obs	188827

$^{***}p < 0.001$; $^{**}p < 0.01$; $^{*}p < 0.05$; $^{\cdot}p < 0.1$

Table 3: Logit model, impact of plot characteristic on organic farming practice

Variable	Treated	All data (before match)	Match Nearest (1) with replacement, caliper 0.005	Match Nearest(2) with replacement, caliper 0.005 k=5
Prediction Logit	0.115	0.08***	0.116	0.115
Texture (ref: Coarse)	0.14	0.12	0.14	0.15
Medium	0.45	0.47	0.46	0.46
Medium Fine	0.25	0.29	0.26	0.25
Fine	0.16	0.12	0.14	0.14
Slope (ref: Level)	0.69	0.74	0.69	0.68
Sloping	0.24	0.21	0.24	0.24
Moderately steep	0.07	0.05	0.07	0.08
Mean Temperature				
Summer	19.03	18.72***	18.99·	19.01
Winter	5.58	5.45***	5.56	5.57
Autumn	9.99	9.82***	9.96·	9.98
Spring	12.87	12.7***	12.85·	12.86
Sum Rainfall (/100ml)				
Summer	1.32	1.35***	1.33*	1.33
Winter	1.75	1.76***	1.75	1.75
Autumn	2.13	2.11***	2.14*	2.13
Spring	1.79	1.76***	1.8	1.8
Year (ref: 2017)	0.20	0.26**	0.2	0.19
2018	0.23	0.26***	0.23	0.23
2019	0.29	0.26***	0.28	0.29
2020	0.29	0.22***	0.27	0.28

Significantly different means between treated group and the potential control group in a t-test for equality of means at different level
$^{***}p < 0.001$; $^{**}p < 0.01$; $^{*}p < 0.05$; $^{\cdot}p < 0.1$

Table 4: Group comparisons before and after matching

algorithm employed Nearest Neighbor Matching with replacement and included a caliper set at 0.005. For the second algorithm, we allowed up to 5 control observations per treated, as long as the difference in propensity score between the treated and untreated individuals was less than 0.005.

To assess the relevance of these matching methods, we compared them using a Student's t-test for continuous variables and a chi-square test for categorical variables. The purpose was to verify that, on average, the treated observations were comparable to the control observations in terms of the characteristics identified during the modeling of the choice of organic farming practices. As shown in Table 4, all conventional lands have a significantly lower probability of practicing organic farming. We observed that all three matching algorithms effectively homogenized the treatment and control groups in terms of soil characteristics and weather conditions. The matching algorithm with a caliper proved to be the most effective.

Distance-based Matching

The second matching method is based solely on minimising the geographical distance crossed with the year of sale. The 16,349 organic land sales are matched with the 16,349 closest conventional land sales. As indicated in Table 5, the average distance between two matched observations is 1.47 km. Due to this relatively low average proximity, we can hypothesize that this matching approach also controls for unobserved characteristics in our data, such as local land market dynamics (financial capacity of farmers in the area, land demand).

	Mean	Median	Sd	Nb.obs
Match Distance	1.47	0.62	2.1	16349

Table 5: Descriptive statistics Distance-based matching (in km)

Average Treatment Effect on the Treated

After demonstrating that our two groups are not significantly different in terms of the variables influencing organic farming practices. Since the two matched observations differ only in terms of being organic or conventional, the price difference between the two types of land can be solely explained by the difference in farming practices. This corresponds to calculating the Average Treatment Effect on the Treated (ATT). The results from Table 6 summarize the ATT for different matching methods. The table indicates that for matchings (1) and (2), which are based on propensity score matching, organic land is sold at an average lower price per hectare (ranging from -138€ to -233€) compared to the same land under conventional practices. However, with the distance-based matching (model 3), no significant difference is found between the two types of agriculture.

ATT organic sales/	All data (before match)	Match Nearest (1) with replacement, caliper 0.005	Match Nearest(2) with replacement, caliper 0.005 k=5	Distance-based matching
Ha price	-331.6	-137.64*	-232.89***	51
log Ha price	-0.06***	-0.028**	-0.038***	0.003
Organic obs	15647	15598	15598	16439
Conventional obs	173180	14228	54998	16349

$^{***}p < 0.001, ^{**}p < 0.01, ^{*}p < 0.05$

Table 6: Average Treatment Effect of organic farming on farmland price

5. Discussion on the absence of farmland organic premium price

The results show that organic land is sold at the same price as conventional land, or even cheaper depending on the model. Which is surprising as the environmental quality of organic land is superior to conventional land. The mandatory practices in organic practice allow to improve carbon and water storage and reduce erosion by increasing biomass and natural seedlings (hedges, moors, wasteland, grove). Thus the environmental externalities allowed by the actions of organic farming (rotation, permanent cover and fertilization with compost and green manure) do not seem to be taken into account in land pricing. From these different facts, it seems incomprehensible that the value of organic and conventional land is the same.

However, there may be other reasons for this non-influence or even negative influence of OF practice on the sale price of agricultural land. Nevertheless, it is possible that these positive environmental externalities are taken into account by the market, and thus that there is a farmland premium price but that an increase in transport cost for the farmer buyer cancels them out.

Indeed, if we look at the supply of organic land, there is a problem of under-availability. Indeed, there is

Minimum distance	Mean Org sales	Mean conv sales	Diff t-test
$Sales_{2017-20}$	6.35	3.05	3.3^{***}

$^{***}p < 0.001$

Table 7: Minimum distance to an organic farm and farmland for sale (in km)

relatively less organic land for sale than conventional land, leading to inappropriate geographical positions. Only 11.7% of the agricultural land was farmed organically in 2020. Moreover, these lands are exploited by five years younger farmers on average (45 years old against 49.7 in CF according to the 2010 French agricultural census). Knowing that the leading cause of land sales is retirement, it explains why organic land for sale is scarcer because it is not yet available. We hypothesise a wrong geographical location of organic land. Indeed, as the OF is marginal, the probability for an organic farmer to find a close organic field for sale is lower than for finding a conventional field.

To measure the extent of the low organic supply, we calculated the minimum distance between an organic farm and an organic land for sale and between an organic farm and a conventional land for sale. We did this from the database of land sales used in the article, in which we include the geographical location of all organic farmers notified to the French Organic Agency[11]. Table 7 (51110 farmers), shows that the hypothesis is well tested. Indeed, on average, if an organic farm wishes to acquire land, the closest land will be conventional land. Indeed, there is a 3.3km difference between buying conventional and organic land for an organic farmer. Over the period 2017-20, conventional land for sale was, on average, 3.05km away from organic farms compared to 6.35km for organic land for sale. Finally, this new result indicates that the relatively higher transportation cost when buying organic land reduces its price. Thus, we can hypothesise that if the buyer considers the cost of transport in his acquisition at an equal distance, the organic land will sell more expensive.

6. Conclusion and Limit

In conclusion, thanks to this new database, which provides information on the sale price of agricultural land in relation to farming practices between 2017 and 2020, we have observed that organic land sold at a lower price than conventional land. However, this result does not mean that the market does not consider the environmental impact of organic farming. Indeed, when we look at the demand for agricultural land, we notice that the transportation cost of buying organic land is higher (being 3.3km further away than the conventional land for sale).

It is also important to note that the land price is mainly explained by Ricardian rent. Indeed, our analysis shows that the meteorological conditions vary from one area to another, influencing the productivity of the

[11]Available on the following website:https://annuaire.agencebio.org/

soil; the latter explains the difference in the price of land. However, the soil's physical characteristics (composition or the slope) influence its productivity and, thus, its value on the land market.

As we finally discussed, our analysis focuses on the supply side of the land, so we have left out the demand side. However, as we have just shown, the relatively minor supply of organic land than conventional land leads to a geographic mismatch problem. Organic farms in search of land have easier access to conventional land than organic land. It is therefore not excluded that organic land is finally more valuable, but the higher transport costs reduce this value.

Thus, it would be interesting to know if an OF has more interest in buying already organic land far away rather than converting conventional land closer.

In the future, we intend to go further than the average effect of price differences between organic and conventional land, by testing the heterogeneity of the effect. It may be that organic land in areas with a high organic population is sold at a higher price due to higher demand.

Acknowledgement

This research was supported in part by INRAe and by the *Maison Interuniverstaire des Sciences de l'Homme d'Alsace* (MISHA) of University of Strasbourg.

Bibliography

G. Allaire, E. Cahuzac, E. Maigné, and T. Poméon. Localisation de l'agriculture biologique et accès aux marchés. Revue d'Etudes en Agriculture et Environnement - Review of agricultural and environmental studies, 96(2):277–312, 2015.

T. Amemiya and T. E. MaCurdy. Instrumental-variable estimation of an error-components model. Econometrica, 54(4):869–80, 1986. URL `https://EconPapers.repec.org/RePEc:ecm:emetrp:v:54:y:1986:i:4:p:869-80`.

E. Baldoni, K. d'Artis, P. Ciaian, and D. Drabik. The capitalisation of agricultural subsidies into farmland prices: A meta-analysis of empirical literature. JRC technical report. Publications Office of the European Union, Dec. 2021. ISBN 9789276444688. doi: 10.2760/028215.

B. Ballet. L'occupation du sol entre 1982 et 2018. Agreste, les dossiers, (April 2021, n°3):746–755, 2021. URL `https://agreste.agriculture.gouv.fr/agreste-web/download/publication/publie/Dos2103/Dossiers%202021-3_TERUTI.pdf`.

P. Barbieri, S. Pellerin, V. Seufert, L. Smith, N. Ramankutty, and T. Nesme. Global option space for organic agriculture is delimited by nitrogen availability. Nature Food, 2(5):363–372, May 2021. ISSN 2662-1355. doi: 10.1038/s43016-021-00276-y.

T. Breusch, G. Mizon, and P. Schmidt. Efficient estimation using panel data. Econometrica, 57(3):695–700, 1989. URL https://EconPapers.repec.org/RePEc:ecm:emetrp:v:57:y:1989:i:3:p:695-700.

J. Cavailhès, M. Hilal, and P. Wavresky. L'influence urbaine sur le prix des terres agricoles et ses conséquences pour l'agriculture. Economie et Statistique / Economics and Statistics, (444-445):99–125, 2011. URL https://hal.inrae.fr/hal-02645617.

J. Cavailhès and P. Wavresky. Urban influences on periurban farmland prices. European Review of Agricultural Economics, 30(3):333–357, 2003. URL https://hal.inrae.fr/hal-02670737.

Eurostat. Land prices and rents, database. 2021. URL https://ec.europa.eu/eurostat/fr/web/products-datasets/product?code=apri_lprc.

French Ministry of Agriculture. Recensement agricole 2020. Âge des exploitants et devenir des exploitations. Agreste primeur 07/2022, 2022.

K. B. Fuller, J. Janzen, and B. Munkhnasan. Farmland rental rates: Does organic certification matter? Land Economics August 19, 2021, 2021. doi: 10.3368/wple.97.1.030119-0032R2.

A. Gattinger, A. Adrian Muller, M. Haeni, C. Skinner, A. Fliessbach, N. Buchmann, P. Mäder, M. Stolze, P. Smith, N. El Hage Scialabba, and U. Niggli. Enhanced top soil carbon stocks under organic farming. Proceedings of the national academy of science of USA, vol. 109 no. 44, page 6, 2012.

F. Geiger, J. Bengtsson, F. Berendse, W. W. Weisser, M. Emmerson, M. B. Morales, P. Ceryngier, J. Liira, T. Tscharntke, C. Winqvist, S. Eggers, R. Bommarco, T. Pärt, V. Bretagnolle, M. Plantegenest, L. W. Clement, C. Dennis, C. Palmer, J. J. Oñate, I. Guerrero, V. Hawro, T. Aavik, C. Thies, A. Flohre, S. Hänke, C. Fischer, P. W. Goedhart, and P. Inchausti. Persistent negative effects of pesticides on biodiversity and biological control potential on european farmland. Basic and Applied Ecology, 11(2): 97–105, 2010. ISSN 1439-1791. doi: https://doi.org/10.1016/j.baae.2009.12.001. URL https://www.sciencedirect.com/science/article/pii/S1439179109001388.

E. G. Gregorich. Carbon distribution and losses: erosion and deposition effects. Soil and Tillage Research, 47,3-4:291–302, 1998.

C. Grout, J. Cavailhes, C. Détang-Dessendre, and A. Thomas. Is Sprawling Residential Behavior Influenced by Climate? Land Economics, 92(2):203–219, 2016. doi: 10.3368/le.92.2.203. URL https://hal.archives-ouvertes.fr/hal-01595376.

J. A. Hausman and W. E. Taylor. Panel data and unobservable individual effects. Econometrica, 49(6): 1377–1398, 1981. ISSN 00129682, 14680262. URL http://www.jstor.org/stable/1911406.

W. Helga, J. Trávníček, C. Meier, and B. Schlatter. The world of organic agriculture. statistics and emerging trends 2021. Research Institute of Organic Agriculture FiBL, Frick, and IFOAM – Organics International, Bonn, 2021.

J. Henderson and S. Moore. The Capitalization of Wildlife Recreation Income into Farmland Values. Journal of Agricultural and Applied Economics, 38(3):597–610, December 2006. URL https://ideas.repec.org/a/cup/jagaec/v38y2006i03p597-610_02.html.

IPCC. Emissions scenarios. Nebojsa Nakicenovic and Rob Swart (Eds.) Cambridge University Press, page 570, 2000. URL https://www.cambridge.org/ch/academic/collections/ipccreports#GXqHTJgjKeLeJeAb.97.

A. Kiflu and S. Beyene. Effects of different land use systems on selected soil properties in south ethiopia. Journal of Soil Science and Environmental Management, 4:100–107, 2013.

S. Kilian, J. Anton, N. Roder, and K. Salhofer. Impacts Of 2003 Cap Reform On Land Prices: From Theory To Empirical Results. 109th Seminar, November 20-21, 2008, Viterbo, Italy 44808, European Association of Agricultural Economists, Nov. 2008. URL https://ideas.repec.org/p/ags/eaa109/44808.html.

L. Latruffe, C. Nauges, and Y. Desjeux. Le rôle des facteurs économiques dans la décision de conversion à l'agriculture biologique. Innovations Agronomiques, 32:259–269, 2013. URL https://hal.archives-ouvertes.fr/hal-01189694.

R. Levesque. Essor résidentiel des campagnes et développement durable. Pour, (195):72–79, 2007. doi: https://doi.org/10.3917/pour.195.0072.

D. Lotter, R. Seidel, and W. Liebhardt. The performance of organic and conventional cropping systems in an extreme climate year. American Journal of Alternative Agriculture, 18(3):146–154, 2003. doi: 10.1079/AJAA200345.

R. Mendelsohn, W. D. Nordhaus, and D. Shaw. The impact of global warming on agriculture: A ricardian analysis. The American Economic Review, 84(4):753–771, 1994. ISSN 00028282. URL http://www.jstor.org/stable/2118029.

A. Muller, C. Schader, N. El-Hage Sciabba, and al. Strategies for feeding the world more sustainably with organic agriculture. Nature Communication, 8, 2017. doi: https://doi.org/10.1038/s41467-017-01410-w.

P. Nguyen-Van, A. Stenger, and E. Veron. Spatial factors influencing the territorial gaps of organic farming in france. (2408-2021-1540), 2021. doi: 10.22004/ag.econ.311087. URL http://ageconsearch.umn.edu/record/311087.

S. Padel. Conversion to organic farming: A typical example of the diffusion of an innovation? Sociologia Ruralis, 41(1), pages 40–61, 2001.

P. Panagos, M. Van Liedekerke, A. Jones, and L. Montanarella. European soil data centre: Response to european policy support and public data requirements. Land Use Policy, 29(2):329–338, 2012. ISSN 0264-8377. doi: https://doi.org/10.1016/j.landusepol.2011.07.003. URL https://www.sciencedirect.com/science/article/pii/S0264837711000718.

S. Passel, E. Massetti, and R. Mendelsohn. A ricardian analysis of the impact of climate change on european agriculture. Environmental Resource Economics, 67(4):725–760, 2017. URL https://EconPapers.repec.org/RePEc:kap:enreec:v:67:y:2017:i:4:d:10.1007_s10640-016-0001-y.

L. Ponisio, L. Gonigle, K. Mace, J. Palomino, P. de Valpine, and C. Kremen. Diversification practices reduce organic to conventional yield gap. Proc. R. Soc. B 282: 20141396, 2015.

J. P. Reganold, L. F. Elliott, and Y. L. Unger. Long-term effects of organic and conventional farming on soil erosion. Nature, 330(6146):370–372, Nov. 1987. doi: 10.1038/330370a0.

D. Ricardo. On the Principles of Political Economy and Taxation. London: John Murray, 1817.

S. Rosen. Hedonic prices and implicit markets: Product differentiation in pure competition. Journal of Political Economy, 82(1):34–55, 1974. URL https://EconPapers.repec.org/RePEc:ucp:jpolec:v:82:y:1974:i:1:p:34-55.

P. R. Rosenbaum and D. B. Rubin. The central role of the propensity score in observational studies for causal effects. Biometrika, 70(1):41–55, 04 1983. ISSN 0006-3444. doi: 10.1093/biomet/70.1.41. URL https://doi.org/10.1093/biomet/70.1.41.

L. Rusinamhodzi, M. Corbeels, M. van Wijk, M. Rufino, J. Nyamangara, and K. Giller. A meta-analysis of long-term effects of conservation agriculture on maize grain yield under rain-fed conditions. Agronomy for Sustainable Development, 31(4):657–673, 2011. ISSN 1774-0746. doi: 10.1007/s13593-011-0040-2.

N. Sautereau and M. Benoit. Quantifier et chiffrer économiquement les externalités de l'agriculture biologique ? Etude ITAB Externalités de l'AB , 2016.

E. Schmidtner, C. Lippert, B. Engler, M. Häring, J. Aurbacher, and S. Dabbert. Spatial distribution of organic farming in germany: does neighbourhood matter ? European Review of Agricultural Economics 39 (4), pages 661–683, 2012.

V. Seufert, N. Ramankutty, and J. Foley. Comparing the yields of organic and conventional agriculture. Nature 485, pages 229–232, 2012.

E. A. Stuart. Matching Methods for Causal Inference: A Review and a Look Forward. Statistical Science, 25(1):1 – 21, 2010. doi: 10.1214/09-STS313. URL https://doi.org/10.1214/09-STS313.

S. L. Tuck, C. Winqvist, F. Mota, J. Ahnström, L. A. Turnbull, and J. Bengtsson. Land-use intensity and the effects of organic farming on biodiversity: a hierarchical meta-analysis. Journal of Applied Ecology, 51(3):746–755, 2014. doi: https://doi.org/10.1111/1365-2664.12219. URL https://besjournals.onlinelibrary.wiley.com/doi/abs/10.1111/1365-2664.12219.

T. Underwood, C. McCullum-Gomez, A. Harmon, and S. Roberts. Organic agriculture supports biodiversity and sustainable food production. Journal of Hunger & Environmental Nutrition, 6(4):398–423, 2011. doi: 10.1080/19320248.2011.627301. URL https://doi.org/10.1080/19320248.2011.627301.

B. Usowicz and J. Lipiec. Spatial variability of soil properties and cereal yield in a cultivated field on sandy soil. Soil and Tillage Research, 174:241–250, 2017. ISSN 0167-1987. doi: https://doi.org/10.1016/j.still.2017.07.015. URL https://www.sciencedirect.com/science/article/pii/S0167198717301423.

7. Appendix

Appendix 1: Comparative analysis of income between organic and conventional farmers

In order to determine the impact of organic practice on economic performance, based on the FADN panel(2004-2019), we perform a panel data regression. Panel data allow us to follow a farmer over several periods. This type of data, compared to cross-sectional data, allows to control for unobservable individual or temporal heterogeneity, as well as to observe the dynamics of the dependent variable of our model.

The rejection of the Hausmann test in the table8, indicates the effect of individual heterogeneity on the dependent variable. But we suspect that individual heterogeneity is correlated with the explanatory variables. Indeed, the individual characteristics of the farmer as well as his geographical environment, according to Padel (2001), Nguyen-Van et al. (2021), influence the practice of OF. However, the modelling of fixed effects by the estimator *within*, equation (7) here is not relevant for Hausman and Taylor (1981).

$$\mathrm{y}_{it} - \overline{y}_i = (Org_{it} - \overline{O}rg_i)\beta_1 + (X_{it} - \overline{X}_i)\beta_2 + (\mu_{it} - \overline{\mu}_i) + (\varepsilon_{it} - \overline{\varepsilon}_{it}) \ (3)$$

Indeed, this estimator does not take into account variables that are constant over time. Indeed, in our database, either the farmer is practising conventional or OF, so if he does not change his practice during the period, the variable will always be equal to 0 and cannot be estimated. In order to overcome these limits, Hausman and Taylor (1981) proposes the following model:

$$\mathrm{y}_{it} = X_{1it}\beta_1 + X_{2it}\beta_2 + Z_{1i}\gamma_1 + Z_{2i}\gamma_2 + \mu_i + \varepsilon_{it} \ (4)$$

y_{it}: [GOS[12]; Total Cost; AWU; Subsidies]

X_{1it}: Time variant variable uncorrelated with μ_i [Temperature, precipitation]

X_{2it}: Time variant variable correlated with μ_i [Type of product, Farm size]

Z_{1it}: Time invariant variable uncorrelated with μ_i [Municipality type]

Z_{2it}: Time invariant variable correlated with μ_i [Organic]

[12]Gross Operating Surplus = Total revenue - Total Cost + Subsidies

We will also estimate the model using the estimators developed by Amemiya and MaCurdy (1986) and that of Breusch et al. (1989), both of which increase the precision of the Hausman-Taylor estimator by increasing the number of instrumental variables based on the hypothesis of strict exogeneity of the variables X_{1t} (i.e $E(\varepsilon_t|X_{1t}) = 0$ and $E(Y_t|X_{1t}) = X_t\beta$).

	log GOS (1)	log Total Cost (2)	AWU (3)	log Subsidies (4)
Farming characteristic				
Organic	0.01	-0.18***	0.16***	0.91***
Agriculture Area	0.005***	0.004***	0.006***	0.006***
Type of product (Livestock ref)				
Cereales	-0.07***	-0.01	-0.33***	0.04
Vegetables	0.48***	0.1***	3.52***	-3.5***
Winegrowing	0.058***	-0.43***	1.76***	-4.77***
Climatic characteristic				
Temperature Mean				
Summer	-0.08***	-0.03***	-0.006	0.06***
Winter	0.02***	0	0.01*	0.03**
Automn	-0.02***	0.007**	0.02**	0
Spring	0	-0.015	0.02***	0
Precipitation Sum				
Summer	0	-0.0001***	-0.0001*	0
Winter	0.0001***	0	-0.0002**	0.0001**
Automn	0.0001***	0	0	0
Spring	-0.001***	0	0	-0.0001***
Intercept	12.1***	11.1***	1.26***	7.4***
Municipality type	YES	YES	YES	YES
Year	YES	YES	YES	YES
R^2	0.12	0.18	0.055	0.15
Nb Obs	98843	102113	102113	102113
Estimator	BMS	BMS	BMS	BMS
H Test $\chi_{37}(\alpha = 0.001) = 55.73$	79	1675	263	174

Table 8: Profitability analysis, period 2004-2019, Breusch-Mizon-Schmidt Estimator

Appendix 2: Descriptive statistics of variables

Table 9: Descriptive statistics of the continue variables

Variable	Definition	Nb. Obs	Min	Max	Mean	Std. Dev	Source
Area	Size of the plot sold (in hectares)	459430	0.0002	1068	10.9	22.9	DVF
Av temperature	Average temperature each season between 1979 and 2020, 25km Grid						European Joint Research Center
Summer		459429	9.1	24	18.8	1.5	
Winter		459429	-5.8	10.4	5.3	1.7	
Autumn		459429	-0.6	15.5	9.7	1.5	
Spring		459429	2	16.6	12.7	1.5	
Av precipitation	Average precipitation each season between 1979 and 2020, 25km Grid						European Joint Research Center
Summer		459429	42.1	237.6	137	28.8	
Winter		459429	109.2	327.8	175.9	31.3	
Autumn		459429	155.7	412.9	213.1	33.4	
Spring		459429	99.3	306.7	178.7	32.2	
Artificialisation growth	Share of the municipality's surface area that has changed from natural to urbanized betwenn 2009-2019	459424	0	21.96	0.5	0.68	French Artificialisation Observatory
Population Growth	Population growth rate of the municipality during 2012 and 2017 (%)	459424	-45.8	511	0.91	7.03	INSEE

Table 10: Descriptive statistics of the discrete variables

Variable	Definition/Source	Value	Nb.obs	%
Organic	Type of farming soil at the time of sale /DVF and RPG	0 = Conventional practice	420854	91.6
		1= Organic practice	38576	8.4
Texture	Dominant surface textural class 10km grid /European Soil Data Center	Coarse (18% < clay and > 65% sand)	63202	13.9
		Medium (18% < clay < 35% and >=15% sand, or 18% < clay and 15% < sand < 65%)	215072	47.3
		Medium Fine (< 35% clay and < 15% sand)	124487	27.4
		Fine (35% < clay < 60%)	51857	11.4
Slope	Dominant slope class 10km grid /European Soil Data Center	Level (dominant slope ranging from 0 to 8%)	333386	73.6
		Sloping (dominant slope ranging from 8 to 15%)	97056	21.4
		Moderately steep (dominant slope ranging from 15 to 25%)	22625	5.0
Year	Year the land was sold /DVF	2017	110330	24.0
		2018	117485	25.6
		2019	123891	27.0
		2020	107724	23.4
Urban class	Classification of municipality regarding nb jobs /INSEE	City of +10000 jobs	25421	5.5
		Surburb of one 10000 jobs city	136158	3
		Surburb of some 10000 jobs cities	46522	1
		City of +5000 jobs	6288	1.4
		Surburb of one 5000 jobs city	9462	2.1
		City of +1500 jobs	17013	3.7
		Surburb of one 1500 jobs city	5964	1.3
		Surburb of some cities	101319	22
		Isolated city	111282	24.2

Appendix 3: Group crops regression

	2017-2020		
	(1)	(2)	(3)
Crops Group (ref: Soft Wheat)			
Grain and silage maize	-0.01	-0.01	-0.01*
Barley	0.03***	0.03***	0.03***
Other cereals	-0.10***	-0.10***	-0.11***
Rapeseed	0.04***	0.04***	0.04***
Sunflower	0.09***	0.08***	0.08***
Other oilseeds	0.04*	0.03*	0.03
Protein crops	0.04*	0.03*	0.03*
Fibre plants	0.16***	0.14***	0.14***
Frozen areas	-0.01	-0.01	-0.01
Rice	0.85***	1.00***	1.02***
Leguminous crops	0.18***	0.19***	0.18***
Fodder	-0.11***	-0.11***	-0.11***
Pastures and heaths	-0.75***	-0.75***	-0.74***
Permanent grassland	-0.33***	-0.34***	-0.34***
Temporary grassland	-0.28***	-0.28***	-0.28***
Orchards	0.34***	0.35***	0.34***
Vineyards	0.36***	0.36***	0.36***
Nuts	0.25***	0.24***	0.24***
Olive trees	0.27***	0.26***	0.27***
Other industrial crops	0.30***	0.30***	0.30***
Vegetables or flowers	0.17***	0.18***	0.17***
Others	0.00	0.00	0.00
ORG*Grain and silage maize	0.01	0.01	0.01
ORG*Barley	0.05	0.06	0.06
ORG*Other cereals	-0.00	-0.00	-0.00
ORG*Rapeseed	-0.07	-0.07	-0.08
ORG*Sunflower	0.07	0.06	0.06
ORG*Other oilseeds	0.16***	0.17***	0.17***
ORG*Protein crops	0.00	0.02	0.01
ORG*Fibre plants	-0.10	-0.09	-0.08
ORG*Frozen areas	0.15***	0.15***	0.15***
ORG*Rice	-0.01	0.05	0.06
ORG*Leguminous crops	-0.12*	-0.12*	-0.12*
ORG*Fodder	0.01	0.02	0.01
ORG*Pastures and heaths	-0.00	-0.01	-0.01
ORG*Permanent grassland	0.03	0.03	0.03
ORG*Temporary grassland	0.16***	0.16***	0.16***
ORG*Orchards	-0.05	-0.04	-0.04
ORG*Vineyards	0.10**	0.10**	0.10**
ORG*Nuts	-0.55***	-0.56***	-0.54***
ORG*Olive trees	0.31*	0.28*	0.28*
ORG*Other industrial crops	-0.41***	-0.45***	-0.44***
ORG*Vegetables or flowers	0.04	0.03	0.04
ORG*Others	-0.08	-0.08	-0.08

$^{***}p < 0.001$; $^{**}p < 0.01$; $^{*}p < 0.05$

Table 11: Second part of farmland price decomposition, crop group impact