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Abstract

The economic performance of organic dairy farms, especially during the transitional period, is not consensus in economics studies, depending on the method used, the type of indicators, the nature and scale of the performance indicator, the geographical location. We compare the economic and financial performance of both conventional and organic dairy farms based on a mixed effect panel data model estimated on 1,016 farm micro-data collected between 2007and 2018 in two departments of Brittany. As in other studies, we find that the herd size influences positively all economic and financial indicators. Even if the growth in assets is heterogeneous among organic farms, it is higher than in other farms, which decreases their return on assets. Finally, even if they share the same objective of food autonomy and sparing variable expenses, dairy farms based on grassland production system do not exhibit the same performance dynamics as organic farms.

Keywords: organic farms, economical and financial performance, mixed effect model

JEL classification: Q14, Q15, C23

Les performances économiques des exploitations laitières en agriculture biologique pendant et après la période de conversion : une approche économétrique sur données de panel en Bretagne

Résumé

La littérature existante sur les performances des exploitations biologiques est abondante, mais il est encore difficile aujourd'hui d'identifier les résultats spécifiques de performance des exploitations biologiques dans la mesure où les échantillons sont très petits. Les résultats obtenus sont également très dépendants des régions et des secteurs agricoles étudiés, des indicateurs de performance économique et des méthodes utilisées. Dans ce papier, nous comparons les performances économiques et financières des exploitations laitières conventionnelles et biologiques à partir d'un modèle à effets mixtes estimé sur 1 016 micro-données collectées entre 2007 et 2018 dans le département d'Ille-et-Vilaine (Bretagne, France). Comme dans d'autres études, nous constatons que la taille du troupeau influence positivement tous les indicateurs économiques et financiers. Même si la croissance des actifs est hétérogène entre les exploitations biologiques, elle est plus élevée que dans les autres exploitations, ce qui diminue leur rendement sur actifs. Enfin, même si elles partagent le même objectif d'autonomie alimentaire et d'économie de charges variables, les exploitations laitières basées sur un système de production herbager ne présentent pas la même dynamique de performance que les exploitations biologiques.

Mots clés : agriculture biologique, performances économiques et financières, modèle à effets mixtes.

Classification JEL : Q14, Q15, C23

1. Introduction

The existing literature on the ex post performance of organic farms, compared to conventional farms, is extensive, but it is still difficult today to identify the specific performance outcomes of organic farms insofar as the samples are very small (Dedieu *et al.*, 2017). The results obtained are also highly dependent on the regions and agricultural sectors studied, the economic performance indicators, and the methods used to avoid bias in the comparison between production systems. There is no consensus in the scientific literature.

Dedieu *et al.* (2017) and Pavie *et al.* (2012) propose descriptive statistical analyses, and they have consistent results. Farms that have converted to organic farming generate, on average, a higher income than other comparable farms. This higher income, expressed as earnings before interests, taxes, depreciation and amortization (EBITDA) or margin per hectare, is partly explained by higher levels of direct subsidies from the Common Agricultural Policy (CAP) (subsidy for conversion or maintenance of organic farming in the EU) and by a higher selling price of labelled products after conversion. Econometric studies such as those of Delbridge *et al.* (2013), Patil *et al.* (2014) and others show that organic farms have better economic performance thanks to lower production costs and/or better selling prices. Other studies mobilize matching methods on samples where groups of organic farms are often small (Uematsu and Mishra, 2012; Guyomard *et al.*, 2013; Froelich *et al.*, 2018). These works show more varied results; the production costs of organic farms are very high, which strongly penalizes their competitiveness. In a sample of 2,689 field crop farms, of which only 65 were organic in 2008, Uematsu and Mishra. (2012) find that organic farmers do not have significantly higher incomes than conventional ones because of higher labour, insurance, and marketing costs. The authors point out that their results could be different on livestock farms. Using 2008 census data, Froelich *et al.* (2018) find that out of more than 4 million farms in Brazil, nearly 75,000 are organic, 3,616 of which are certified. They also find that across all orientations, organic farmers have statistically lower incomes. In this paper, we propose to compare the economic and financial performance of both conventional and organic dairy farms.Our analysis differs from the existing literature in two ways. First, we use a fixed-effects and random-effects model to exploit the longitudinal dimension of our data (2007-2018) and attempt to identify the specific effect of belonging to an organic label on the economic performance of farms. This first step also allows us to explore the potential effects of other performance determinants, such as size, more or less intensive production systems and other unobservable individual characteristics. Second, we complete this study by analysing the impact of the conversion period on the performance of organic farms.

To differentiate the impact of individual farm specificities (related to their size, the choice of more or less intensive production system or the characteristics of the farmer) on their performance from the effects induced by organic farming, we build a linear mixed model with analysis of variance components, as done by Wolf *et al.* (2016) on U.S. dairy farms. They evaluate the financial performance of U.S. dairy farms using profitability, solvency and liquidity indicators. Their approach allows to show that, among other things, large farms have a better financial performance than small farms when economic conditions are favourable but they obtain the same performance as small farms in bad years. The benefit of this statistical model is to control, in a simple way, for individual specificities via a random effect and for temporal specificities via a fixed effect to identify the impact of organic farming on performance via another fixed effect. We also control for the effect of farm size on farm performance. The effect of farm size and economies of scale on farm economic performance is well known and debated in the agricultural economic literature. Between 1987 and 2007, in the United States, the 30% growth in milk production was accompanied by a sharp decline in the number of dairy cows and a strong increase in productivity per cow. The restructuring of farms towards large to very large sizes confirms the presence of economies of scale (Mosheim and Lovell, 2009). However, according to Chavas, there is no evidence that economies of scale in dairy farming persist at very large sizes (Chavas, 2001). Chavas indicates that the returns to scale would be rather constant for large sizes, especially if one considers that part of the cost of labour is not taken into account. The coexistence of very different sizes of dairy farms can also be explained by multiple factors, including public policy, risk, transaction or adjustment costs and the slowing down of technological change.

Using the same statistical approach as Wolf *et al.* (2016), in the second part we analyse the impact of the transition to organic farming on the economic and financial performance of dairy farms. The conversion to organic farming is a transition period of two years for annual crops in the European Union, during which farmers must suspend all use of synthetic chemical inputs and antibiotics in livestock production without being able to sell their production at a higher price under the "Organic Agriculture" (AB) label. During this period, the farm income may decrease, so that exit decisions may occur during this period (Läpple, 2010). In dairy farms, it is often also an investment phase in the purchase of animals and new equipment, as well as the reconfiguration of production and cultivated areas to produce more forage and/or feedstuff for the herd. This phase is similar to a progressive transformation of the production system. In the short term, this transformation generates tension in the farm's cash flow. Using a normative approach of ex-ante simulations based on linear programming models calibrated on Belgian

FADN[1] data (685 conventional farms monitored between 1999 and 2001) for several production orientations, Kerselaers *et al.* (2007) show that the economic potential of conversion can be divided by two for dairy farms due to higher risks and lower cash flow during the conversion period. Some of the feed for the herd, which is guaranteed in the organic sector, can be more expensive, even though organic farms have a higher overall feed autonomy than conventional farms and a lower use of purchased feed. The level of purchases and external expenses per dairy cow was estimated to be 20% lower in organic dairy production in 2013 in France (Dedieu *et al.*, 2017). However, operating revenues may also decrease due to the combined effect of lower yields and the temporary restriction on selling production under the AB label. In addition to these short-term constraints, the transformation of the farm towards a more autonomous system in the long term can also make it more economically and financially efficient. Indeed, less dependence on external inputs can reduce exposure to market risks, increase the capacity to absorb certain shocks and make the farm more resilient (Veysset and Delaby, 2018). Few data track farms before, during, and after their conversion to organic production, hence the lack of economic studies on the dynamics of farm conversion and the limitations encountered by farms during this conversion phase. However, some works propose an econometric assessment of the performance of farms who choose to convert to organic farming. Using detailed farm level information on production and cost among a panel of 279 dairy farms, of which 49 are organic, from 1995 to 2002 in Finland, Kumbhakar *et al.* (2009) found that inefficiency decreases the probability of adopting or continuing organic farming. Already-efficient conventional farms might be more attracted to switching to organic than less-efficient ones. Adapting the same methodology of technical efficiency analysis on a sample of 7,946 French FADNfarms, of which only 66 converted to organic, during the 2003-2007 years, Latruffe and Nauges (2014) found a similar result for field crop farms. Farmers who convert to organic have higher scores of technical efficiency than those who keep with conventional systems. Both works suggest a sort of selection bias among farms. Those would choose to convert to organic farming already have a higher economic of technical performance.

2. Methodology

Our objective is to evaluate the economic and financial performance of dairy farms and to analyse, using a linear mixed-effects model, whether organic label membership or other farm

[1] Farm Accountancy Data Network

characteristics such as size or production system are correlated with significant differences in performance. Some of the farms in our sample are in the conversion stage.

2.1. The linear mixed-effects model

The economic and financial performance of farms can be influenced by multiple factors: improved productivity allowed by better technical performance (linked to the characteristics of the farm such as its size and its level of mechanization, or to the characteristics of the farmer such as his individual skills, experience and training), exogenous factors such as climate or a more favourable price situation, or the existence of better prices durably linked to belonging to a label such as organic. To differentiate the impact of individual farm specificities on their performance from the effects induced by organic farming, we build a linear mixed-effects model, as done by Wolf *et al.* (2016) on U.S. dairy farms. Such a statistical model makes it possible to control, in a simple way, for individual specifics via a random effect and time specifics via a fixed effect to identify the impact of organic farming on performance via another fixed effect.

Indeed, the random effect allows us to consider only the variability related to the farm, without having to detail in the model those variables describing the specificities of the farms in terms of agricultural practices or farm structure. This variability is embedded by adding to the model a random constant u_i specific to each farm. This random effect is characterized by a variance parameter that must be estimated in addition to the variance of the model errors ε_{itk}. The random variable u_i follows a normal distribution $N(0, \sigma_u^2)$, where σ_u^2 is the inter-subject variance. The random variable ε_{itk} follows a normal distribution $N(0, \sigma_\varepsilon^2)$, where σ_ε^2 is the within-subject variance. We assume that these random variables u_i and ε_{itk} are independent.

The fixed effects allow us to control for a possible time effect and to identify whether belonging to a group, particularly to the group of organic farms, impacts the economic and financial performance of the farms (equation 1).

$$y_{itk} = \mu + \gamma_t + \sum_k \tau_k + \sum_k (\gamma\tau)_{tk} + u_i + \sum_k \varepsilon_{itk} \qquad (1)$$

where y_{itk} corresponds to the performance indicator observed at time *t* of individual *i* in group *k*; and the fixed effect term μ corresponds to the mean. The term γ_t represents the deviation from the mean associated with time *t*. The term τ_k represents the deviation from the mean associated with group *k*. In our model, we will define two groups, one group representing the production systems (*k=1*), in particular the organic farming system, and the other group representing the size of the farms (*k=2*). The term$(\gamma\tau)_{tk}$ represents the deviation from the mean associated with the interaction of time t and group *k*. The term $\mu + \gamma_t + \tau_k + (\gamma\tau)_{tk}$ corresponds to the fixed and deterministic part of the model, while the term $u_i + \varepsilon_{itkh}$ corresponds to the random part. This equation corresponds to a model with only one group.

2.2. Economic and financial performance indicators

To measure the performance of farms and their ability to cope with production or market shocks, we rely on traditional performance indicators. These are based on four dimensions of the economic and financial performance of the farm: its profitability, return on assets, solvency and liquidity (Wolf *et al.*, 2016; Picaud *et al.*, 2015).

We approach the profitability of farms, *i.e.* their capacity to create wealth, by controlling their intermediate consumption *via* two main indicators: on the one hand, the ratio of net profit to sales, known as the gross profit margin (GPM) or margin rate, shows the percentage of sales that a company retains after covering all costs; on the other hand, the EBITDA or gross operating profit, is the second indicator of profitability that measures the wealth created by the company once intermediate consumption and salary costs have been removed from production and operating subsidies (mainly CAP subsidies) have been added. In the analysis of profitability, we also use the milk gross margin (GM) indicator per litre of milk produced. This indicator balances milk sales and operating expenses (costs of feed purchases, veterinary and breeding expenses) of dairy activity. The rate of return on assets (ROA) is defined as operating income divided by total assets and reflects the ability of firms to use assets, both fixed and current, to generate profits. The debt-to-asset ratio (DA) is used to assess the solvency of firms. It is the ratio of total debt to total assets of the firm. The current ratio (CR) is a liquidity ratio that indicates the amount of cash and cash equivalents in proportion to short-term obligations, measuring the capacity of a firm to meet its short-term obligations. To complete our approach to the solvency of the firm, we use a final indicator, cash flow. Cash flow (CF) is equal to the balance between, on the one hand, the resources that the firm generates in the long term as a result of its policy of financing fixed assets and the income from its activity and, on the other hand, the financing needs of the activity in the short term (working capital requirements). The elements likely to influence cash flow are both "top line" elements (investments, such as those made during the conversion, and the results of previous years) and "bottom line" elements (inventories, operating debts and receivables). A positive cash flow reflects the flexibility of firms to deal with unforeseen events without having to rely on external funds. A negative cash flow indicates short-term borrowing and a shortage of cash. This indicator, therefore, provides insights into the financial health of a farm. The interpretation of this indicator remains delicate, however, since the level of cash flow is essentially very volatile, as it is highly dependent on market or weather volatility in a given year as well as on investment choices, which vary greatly from one company to another. These indicators reflect the short-term performance of farms.

One indicator that can measure the long-term performance of firms is the total growth rate of assets (GRA). It measures the percentage change in a firm's assets from one year to the next and is equal to the total assets of one year over the total assets of the previous year minus 1. This indicator reflects the increase in the size and financial strength of a firm from one year to the next.

The profitability (EBITDA, GM and GPM) and rate of return (ROA) indicators are, by construction, directly influenced by the technical and economic performance of the enterprise. They can be influenced by individual farm characteristics (e.g., age, training, operator skills, type of production system), prices and weather conditions. They can also be influenced by the size of the herd and the existence of economies of scale through the reduction of unit fixed costs. On the other hand, the two solvency indicators (DA and CR) may be correlated with individual farm characteristics, but these correlations may have multiple sources. These two indicators may depend on the economic performance of the farm, but their evolution may also be strongly influenced by the choices the farm has made to finance its investments. A correlation can be expected between the level of investment (and therefore the size) of the farm and its level of debt (and therefore its debt ratio). The current ratio (CR) and the debt ratio (DR) can be influenced by cash flow problems caused by asset growth, such as when converting to organic farming or following an investment. However, these solvency ratios are also influenced by the current and past financial management of the farm, which can disrupt the reading of their evolution, including the trade-offs made by the farmers or partners between consumption, savings and investment and the negotiation of financing obtained from banking organizations.

2. Data

We have individual accounting data provided by CER FRANCE Brocéliande (a management and accountancy agency for farms operating in the departments of Ille-et-Vilaine and Morbihan, Brittany). This database lists the private accounting data of both organic and conventional dairy farms in Ille-et-Vilaine, which is the leading French department in terms of milk production. It contains 1,016 dairy farms, 62 of which are or are converting to organic farming during the period. We have an unbalanced panel over 12 years; from 2007 to 2018, each farm was followed between 2 and 12 years, leading to a total of 5,918 observations.

We classify the farms of our sample into three categories: organic farming systems[2], conventional-forage maize systems and grassland systems. To distinguish "maize" systems from "grassland" systems, we use the criteria set in the framework of the "mixed farming system" agro-environmental climate measures (MAEC - SPE) implemented with the 2015 CAP. To receive a payment, the contracting farms must respect, among other things, constraints on their share of maize and grass in their farm. In this study, we consider a system to be grassland when its share of maize in the main forage area (MFA) is less than 28% and its share of grass in the utilised agricultural area (UAA) is greater than 55%, which corresponds to the necessary conditions of this MAEC to obtain the lowest remuneration (MAEC type "SPE3"). From this classification, we obtain a category composed of 169 observations of organic systems, one of 483 observations of grassland systems and one of 5,266 observations of maize systems. As the farms in this last category are very numerous and heterogeneous, we propose to distinguish two subgroups of maize systems, according to their share of corn fodder in the main forage area (MFA) based on a statistical classification that distinguishes the most intensive systems (maize system 1) (53% of corn in the MFA on average) from the others (maize system 2) (38%).

We identified a few characteristics of organic systems (especially in the dairy sector) describing their production technology and on which there is a consensus in the literature. These findings are confirmed by the descriptive analysis of the different production systems in terms of structural, agronomic and economic characteristics (see Table 1). First, organic farmers value their agricultural products under the organic label and thus benefit from an increase in the value of their selling prices. On average, in our sample, the price of milk is between 25% higher in organic systems, which corresponds to a milk premium of 80 €/ 1 000 litres of milk on average, which can vary depending on the dairy collector. Second, organic farming is based on a sparing and efficient use of variable inputs, especially concentrates, fertilizers and agrochemicals. On average, in our sample, we observe operating expenses in relation to gross product that are approximately 15% lower for organic systems, thanks, in particular, to lower expenses for

[2] The classifications are done by observation, i.e. a farm in a given year. A farm, which is not yet in the conversion period, belongs in the maize system or grassland system. From the year in which the farm begins its conversion to organic, it belongs to the AB group.

concentrates (40% lower for organic systems compared to maize-based systems). Third, given the lower use of concentrates, cattle feeding in organic systems is based essentially on grazed grass or grass silage, which requires more grassland. In our sample, the average utilized agricultural area (UAA) of organic farms is 80 ha (between 60 and 70 ha for other production systems), and 70% of this area is allocated to grassland (between 32 and 46% for corn systems). These last two points allow organic farmers to reach a higher level of food autonomy, which is generally considered a prerequisite for their conversion to organic production. Finally, organic dairy farms rely on animal/plant complementarity to manage soil fertility without the use of synthetic fertilizers and make greater use of meadows and grass to feed the herd to limit the use of external feedstuff. They diversify their crop rotation by implementing longer rotations to manage disease and parasite problems without having to rely on agrochemicals. These complementarities are a source of economies of scope. The dairy farming systems, in our sample, are relatively homogeneous in the sense that they all produce cereals, forages and grassland, yet all of them do not necessarily make optimal use of the interactions between crop and animal production. Some farms seem to be moving towards a simplification pathway and a specialization of dairy activity in search of economies of scale.

Thereafter, we describe the average economic and financial situation of each group, based on the economic and financial performance indicators defined in the previous section (see Table 2). Finally, we analyse the distribution of farms in each production system according to their size, defined by the number of dairy cows (see Table 3). Overall, despite very similar technical and agronomic characteristics of the grassland and organic systems, the organic farms have gross margins per litre of milk produced that are higher on average than the grassland group. On the other hand, the gross margin profit (GMP) and return on assets (ROA) indicators are quite close between the two production systems and seem to be higher than in the systems based on maize. In contrast, the solvency ratio appears to be lower, on average, for organic farms than for conventional farms. This can be explained by a higher level of investment during the conversion phase (e.g., the purchase of animals and equipment, which is confirmed by the greater proportion of large herds in the organic group), which can lead to an increased level of debt. In terms of herd size, the difference was also significant between grassland and organic systems. More than 80% of the grassland systems are small or medium sized, whereas the organic systems are mostly (54%) in the large class (more than 60 cows), which can also be explained by a lower average level of milk productivity than in the grassland systems (i.e., to achieve the same volume, more cows are needed). In addition, if we consider the level of productivity per cow by size-class and by system, it appears that, in the grassland systems, the increase in herd size is not accompanied by a significant change in the level of milk productivity, whereas in the organic sector, this change from small to large herds results in a decrease of 1,000 litres per cow (*cf.* Table 4). Thus, in organic systems, a larger herd size seems to be accompanied by lower milk productivity, as the decrease in milk productivity with size may be a source of diseconomies of scale. But these points should be mitigated considering the very small size of our sample.

Compared to conventional dairy farms, organic farms exhibit an increase in assets (capitalization - GRA indicator in Table 2). This increase seems, on average, to be accompanied by an increase in the rate of return on capital, which would indicate the presence of economies of scale (the investments would be profitable because of higher market prices than conventional milk and lower feed costs).

Table 1: Statistical description of farm categories.

	Corn system 1	Corn system 2	Grass system	Organic system
Number of observations	1 493	3 773	483	169
UAA	69 ha	67 ha	61 ha	80 ha
Share of FC/MFA	53%	38%	21%	16%
Share of grass/MFA	32%	46%	67%	70%
Share of crops/UAA	36%	25%	16%	20%
Total milk produced	434 000 litres	372 000 litres	396 000 litres	376 000 litres
Milk produced per cow	7 657 litres/cow	7 144 litres/cow	6 418 litres/cow	6 075 litres/cow
Number of dairy cows	55.89	52.39	49.34	67.84
Animal density	1.26 cow/ha MFA	1.09 cow/ha MFA	0.96 cow/ha MFA	1. 00 cow/ha MFA
Price of milk	331 €/1000 l	331 €/1000 l	337 €/1000 l	412 €/1000 l
Total aid	792 €/ha	736 €/ha	715 €/ha	933 €/ha
Concentrated costs	443 €/cow	362 €/cow	266 €/cow	219 €/cow
Operating expenses/GP	40%	38%	34%	29%
Operating costs/litre	0.18	0.18	0.17	0.18
Share of feed produced	36%	32%	42%	62%
Asset value	395 000 €	339 000 €	304 000 €	494 000 €
Operating expenses/GP	40%	38%	34%	29%

Notes: FC: fodder corn; MFA: main forage area; UAA: utilized agricultural area; GP: gross product

Table 2: Financial performance of farms.

	Corn system 1	Corn system 2	Grass system	Organic system
GM	222 €/1000 l	235 €/1000 l	260 €/1000 l	338 €/1000 l
EBITDA	54.99 M€	48.04 M€	45.90 M€	80.35 M€
Ratio M	7.91%	8.80%	11.81%	11.71%
Ratio ROA	5.27%	5.75%	6.86%	7.43%
Ratio DA	39.49%	35.93%	32.52%	45.09%
Ratio NC	-2 398	2 790	11 705	4 500
Ratio GRA	0.057	0.049	0.029	0.126

GM: gross margin per litre of milk; EBITDA: gross operating profit; GPM: gross profit margin; ROA: return on assets, DA: debt on assets; CF: net cash flow; GRA: annual growth rate of assets.

Table 3: Distribution of farms by herd size.

Number of dairy cows	<40 dairy cows	[40 – 60] dairy cows	> 60 dairy cows
Corn system 1	19%	48.5%	32.5%
Corn system 2	22%	53%	25%
Grass system	35%	47%	18%
Organic system	10%	35%	54%

Table 4: Milk productivity per cow of farms according to their system and herd size.

Number of dairy cows	<40 dairy cows	[40 – 60] dairy cows	> 60 dairy cows
Corn system 1	7 681 litres/cow	7 554 litres/cow	7 798 litres/cow
Corn system 2	7 096 litres/cow	7 134 litres/cow	7 206 litres/cow
Grass system	6 630 litres/cow	6 366 litres/cow	6 143 litres/cow
Organic system	6 914 litres/cow	6 088 litres/cow	5 912 litres/cow

3. Estimation results

The results are divided into three subsections. First, we analyse the variance components to identify the weight of intra-farm and inter-farm variability in the total variability of the economic and financial indicators. Second, we present the estimated parameters associated with the fixed effects of the model to identify the impact of group membership (by production system, by size and their interaction) on economic performance. Finally, we focus our analysis on the period of conversion to organic production and its impact on the evolution of the economic and financial performance of the farms.

3.1. Analysis of variance components

Time fixed effects and those associated with group membership (size, production system and their interaction) explain part of the variability of the indicators. The parameters associated with these fixed effects are interpreted as deviations from the mean and are presented in the following section. The variability of the indicators not explained by these fixed effects is found either in the individual random effect or in the residual for which we can estimate their variance. The total variability of the indicators is thus decomposed into two sources, the variability within farms, measured by the residual, and the variability between farms in each group, measured by the individual effect. The latter measures the heterogeneity of farms within groups.

The analysis of variance shows that the variability of the DA (solvency) and milk margin GM (profitability) indicators is mainly due (73% for the DA ratio and 78% for the margin) to the variability between farms. Thus, differences in production systems, farming practices, unobservable individual characteristics of farmers (such as managerial attitudes or preferences for risk and time), location and structure from one farm to another, which are included in the randomized individual effect, largely explain the differences observed for these two indicators (see Table 5).

Table 5: Analysis of variance component[3].

	GM	EBITDA	GPM	ROA	DA	CF
Individual effect (inter-farm)	78%	57%	38%	38%	72%	52%
Residual effect (intra-farm)	22%	43%	62%	62%	28%	48%
Total	100%	100%	100%	100%	100%	100%

GM: gross margin per litre of milk; EBITDA: gross operating profit; GPM: margin rate; ROA: return on assets, DA: debt on assets; CF: net cash flow; GCA: annual growth rate of assets.

[3] Calculating the asset growth rate requires us to remove the first observations of each farm from the sample. This reduces our sample size and does not allow us to estimate the variance of the individual effect.

In contrast, the variability in the return on assets (ROA) and margin rate (GPM) is mainly due to intra-farm variability, i.e., changes within the farming system from one year to the next. This can be explained by the investment or disinvestment choices that may be made by the same farm over time. This would confirm that this intra-individual effect would be linked either to production or to market shocks specific to certain farms or to a technological or structural change such as expansion.

3.2. Analysis of fixed effects

The parameters associated with the fixed effects of the model are presented in Table 6. Some parameters are not presented to simplify the presentation of the results. These parameters concern time effects and interaction effects between time effects and size group and between time effects and the production system group, which level is not significant considering the size of the sub-samples.

The constant represents the average of the indicator for the reference group consisting of large farms (over 60 cows) belonging to the most intensive corn-based production system ("corn system 1" group), for the reference year 2018. The parameters associated with the size effect represent the average deviation associated with belonging to the group of farms with the smallest herd size (less than 40 dairy cows) and with medium herd sizes (between 40 and 60 dairy cows). The parameters associated with each production system (organic, grassland and corn system 2) represent the average difference associated with belonging to these production systems compared to the reference group of farms. The interaction parameter between size and production system represents the deviation from the mean associated with being a small or medium farm in a specific production system. Finally, the annual indicator variables represent the mean deviation associated with time effects.

As expected, farm size, measured by the number of cows, significantly impacts almost all economic performance indicators, regardless of the production system. Profitability and return on assets indicators decrease with the size of the herd. It can be assumed that this drop in performance is related to the lower milk yield per cow in these smaller herd sizes and/or the lower dilution of herd-breeding costs that are included in the margin calculation. The descriptive statistics do not confirm this hypothesis, since the operating expenses per litre of milk are not significantly different according to the size of the farms (an average of between 0.17 and 0.18

€/litre of milk for each size group) and the milk productivity is not lower for the smallest farms (cf. table 4). This effect of size would therefore be explained by economies of scale in the set of fixed costs. Several studies have previously demonstrated these results on dairy farms. Tauer and Mishra (2006) show that in American dairy farms, neither the variable cost of producing a unit of milk nor efficiency decrease significantly with farm size. Instead, the fixed cost of production per litre of milk decreases with farm size, and the farm becomes more profitable. However, Chavas (2001) argues that there is no evidence that these economies of scale remains beyond certain sizes.

Regarding profitability indicators, the results of our statistical approach confirm the descriptive statistics presented previously. The organic farms have on average a gross margin per litre of milk that is approximately 30% higher and a gross operating surplus that is approximately 40% higher than the other production systems in our sample (see Table 6). These results can be explained by their lower level of intermediate consumption associated with a significantly higher selling price of milk. On the other hand, the positive effect of the organic system on the profitability indicators seems to be partly neutralized in the small farms. Thus, organic farms with fewer than 40 cows have lower profitability in terms of milk margin and EBITDA than other production systems. The lower margin per litre of milk can be explained by higher structural costs when compared to the total volume of milk produced. These higher structural costs, which can also penalize EBITDA, may be the result of higher wage costs or purchases of services (insurance, etc.) that are not compensated by the higher price of milk.

As far as the indicator of return on assets (ROA) is concerned, and although organic systems were on average better performing than all other production systems (see Table 1), we do not find these results from our econometric model on the solvency (DA) and profitability (ROA) criteria. In contrast, our results show a significant decrease in the ROA of organic farms. This informs us on two points.

First, the lower ROA performance of organic systems can be explained by their investment strategy. Depending on the level of investment at the time of conversion, the level of structural expenses and assets in the denominator of the ratio, is more or less increased. This will mechanically translate into a decrease in the ROA ratio if the operating income, in the numerator, has not increased by the same proportion. It should be noted that many of the organic farms in our sample have been organic for less than 5 years. It is reasonable to estimate that it takes several years for an organic farm to generate profits proportionally higher than the capital invested at the time of conversion. It will be interesting to compare this result with the analysis of the performance of organic farms before, during and after conversion, which will be presented in the next section.

These mixed results on the medium-term profitability of organic farms are consistent with those of Khanal *et al.* (2018), who show that the impact of organic production is variable depending on the production orientation and the level of sales. Uematsu and Mishra (2012) also showed that, although they benefit from higher prices, organic farms also incur higher costs related to labour, marketing, and insurance, which are similar to structural expenses. We particularly find these effects in smaller organic farms.

On the other hand, the difference between the average value of the ROA and the result of our estimation shows that there is a strong diversity of organic farm models associated with different strategies and production conditions from one farm to another. Indeed, for some farms, the conversion to organic farming was accompanied by a strong increase in capital. Others, on the contrary, have maintained a low capital intensity. The heterogeneity of these farms may also stem from their very different adaptation strategies in the face of climatic shocks. Indeed, these systems are probably more sensitive to climatic hazards, as animal feedstuff is less based on the use of concentrates and purchased feeds that would compensate for variations in forage yields, as is the case in forage corn-based systems. Thus, faced with unfavourable weather conditions, these farms will have to make decisions to ensure the provision of feedstuff, which will depend, among other things, on the characteristics of their farm (e.g., location and quality of their soil and plot of land, etc.) and their managerial capacity. The different strategies adopted by the farmers are probably another source of heterogeneity within the organic group. It is also possible that this greater heterogeneity is artificial in the sense that the number of organic farms observed is not sufficient to highlight effects based on average values.

The comparative analysis of economic and financial performance between the different production systems allows us to highlight different determinants between non-organic and organic grazing systems, whereas one might have suspected similar results (Kallas *et al.*, 2010). Thus, although these two systems share common characteristics, in particular the search for food autonomy and spare management of inputs (lower level of variable expenses), we observe a significant difference in the rate of increase of assets. Organic systems have much higher levels of investment, linked to greater quantities of dairy cows (compensating for the lower productivity per cow) for the same volume of milk, and more fodder stocks, whereas fixed expenses remain low in grassland systems.

Table 6: Estimation of fixed effects.

	GM	EBITDA	GPM	ROA	DA	CF	GCA
Constant	207.05**	62.62**	12.59**	9.19**	32.98**	28.18**	-0.01
Herd-size effect (small)	-2.58**	-36.30**	-8.60**	-5.96**	-7.84**	-25.90*	0.06
Herd-size effect (medium)	2.11	-20.07**	-1.98	-0.67	-6.32**	-17.50**	-0.03
System effect (organic)	70.09**	26.79**	-3.19	-5.18**	3.10	18.65	0.20**
System effect (grassland)	-4.04	-5.55	-1.85	-2.96	2.87	26.63**	-0.04
System effect (fodder corn 2)	-2.82	3.77	3.19*	0.81	3.08	9.49	0.03
Interaction effect (organic*small)	-26.80**	-16.71**	-2.36	-1.68	7.73*	-6.34	0.05
Interaction effect (organic * medium)	-11.27	-20.49**	-2.10	-0.47	-4.88	6.04	-0.002
Interaction effect (grassland * small)	-4.35	1.77	1.13	1.29	-0.36	-11.87	0.01
Interaction effect (grassland * medium)	-6.99	-1.44	-0.42	0.34	0.13	-11.63	0.04
Interaction effect (corn 2* small)	5.86*	2.78	1.58	1.36	-0.46	-4.82	-0.009
Interaction effect (corn 2*medium)	2.04	0.92	0.54	0.96	-0.41	-3.25	-0.02
R2	0.80	0.75	0.60	0.59	0.77	0.70	0.32

*** and * statistically* different *from zero* at *the respectively* 5 *% and 10% level* of *confidence.*
GM: gross margin per litre of milk; EBITDA: gross operating profit; GPM: margin rate; ROA: return on assets, DA: debt on assets; CF: net cash flow; GCA: annual growth rate of assets.

3.3. Effect of conversion to an organic system

This second analysis is carried out on a sample composed of farms that are in an organic system or that converted to organic farming during our study period. We have 313 observations over 3 periods: 144 observations before conversion, and 53 observations during conversion, which we define as the year of conversion plus 3 years, and 116 observations after conversion. The reference period is the period before conversion.

Using the same approach as above, we seek to identify the effect of conversion, if any, on economic and financial performance. An effect related to the period before, during and after conversion is thus integrated into the model. We do not have enough observations in each size group to take a size effect into account. The constant corresponds to the farms before conversion. The analysis of variance components is presented in Table 7, and the fixed effects estimation results are presented in Table 8. For clarity, time effects, as well as interactions between time effects and the conversion effect, are not presented in the table.

Table 7: Analysis of variance components.

	GM	EBE	GPM	ROA	DA	CF
Farm effect (inter-farm)	84%	64%	43%	46%	67%	43%
Redisual effet (intra-farm)	16%	35%	57%	54%	33%	57%
Total	100%	100%	100%	100%	100%	100%

GM: gross margin per litre of milk; EBITDA: gross operating profit; GPM: margin rate; ROA: return on assets, DA: debt on assets; CF: net cash flow; GCA: annual growth rate of assets.

For the ratios of return on assets (ROA) and margin rate (GPM), the proportion of variability explained by inter-farm variability is greater than in the total sample (43% and 46 % respectively instead of 38% in Table 5), which suggests greater heterogeneity within organic farms than within other production systems.

Table 8 : Fixed effects estimates

	GM	EBITDA	GPM	ROA	DA	CF	GCA
Constant	337.06**	125.70**	31.17**	20.43**	45.29**	178.35**	-1.65**
Conversion effect (during)	-33.54*	-76.16**	-18.19**	-13.04**	7.12	-83.71**	1.58**
Conversion effect (after)	13.86	-24.75	-16.15	-10.94**	14.77	-19.70**	1.00**
R2	0.91	0.76	0.62	0.93	0.73	0.73	0.70

*** and * statistically* different *from zero* at *the respectively* 5*% and 10% level* of *confidence.*
GM: gross margin per litre of milk; EBITDA: gross operating profit; GPM: margin rate; ROA: return on assets, DA: debt on assets; CF: net cash flow; GCA: annual growth rate of assets.

All profitability and cash flow indicators deteriorate during the conversion period, which is consistent with the increase in assets and the fact that the farms do not yet benefit from the capital gain on sale prices. After the conversion period, we observe, on the one hand, that even though all indicators have improved, the ROA and net cash flow rates are still significantly lower than their pre-conversion levels and, on the other hand, that the profitability indicators (GM, EBITDA and GPM) are not significantly higher than their pre-conversion levels. We also note that the constant of all profitability indicators, which represents the average before the conversion period, is much higher than the constant obtained in the first full sample estimation model, which represents the average of the indicators for large farms in corn systems (Table 5).

There are several possible explanations for these results. This may mean that the farms that convert to organic production have a higher profitability performance before conversion than the other systems in our sample. This would be consistent with the results of Kumbhakar *et al.* (2009). The positive impact of the organic group in the profitability models of the full sample (Table 6) would therefore not be directly related to the organic label alone but also to the specific characteristics of these farms. At the same time, it can be assumed that farms are gradually converting to organic farming, combining both conventional and organic farming. The transition to new practices and associated investments may therefore have started before the official conversion period (Argilés and Brown, 2007).

The high heterogeneity of farms in organic systems, or the low number of observations, may also explain the lack of significance of the post-conversion period on the indicators. It would be necessary to follow the farms converted to organic farming over a greater number of years after conversion to identify significant effects. The strong and relatively recent development of organic farming, however, does not allow us to access such data series.

4. Discussion and conclusion

In this work, we confirm some known results on the determinants of heterogeneity of economic and financial performance of organic dairy cattle farms. While organic farms have higher average profitability and return indicators, we highlight other explanations for the differences in performance observed in the sample. Following Wolf *et al.*'s (2016) approach, we use a mixed-effects panel model, which controls, in a simple way, for individual specifics via a random effect and time specifics via a fixed effect, to identify the impact of organic farming on performance via another fixed effect.

As expected, herd size, measured by the number of cows, significantly impacts almost all economic performance indicators, regardless of the production system. However, if the organic farms have, on average, a higher gross margin per litre of milk and a higher gross operating profit compared to the other production systems in our sample, the effect of the size on the dilution of fixed costs and economies of scale takes a particular turn in the organic system. Indeed, it is difficult to increase the milk yield per cow by forgoing synthetic chemical inputs and by relying more heavily on a diet based on produced feedstuff. Thus, we observe that the average annual growth rate of assets is higher for the organic farmers in our sample because of the increase in capital (herd) and stocks (forage) to produce the same volume of milk. In addition, despite lower variable costs per litre of milk (especially in feed purchases) and higher organic prices, additional fixed costs can occur in the organic system that are related to the workload or to the possible purchase of additional services. Consequently, only the largest herd sizes (over 40 cows) manage to maintain higher average profitability, while small organic herds are less profitable. However, these results must be qualified according to the conversion trajectories followed by individual farms, which are undoubtedly very heterogeneous (some resulting in higher capitalization, others in maintaining the capitalization level).

Regarding the production system, while one could have expected comparable economic performances between organic and grassland farms, which are both seeking food and fodder autonomy, it appears that the increase in assets is the prerogative of organic farms. The latter have higher levels of investment, linked to a larger number of dairy cows (compensating for lower productivity per cow) for the same volume of milk, as well as more fodder stocks, while fixed costs remain low in grassland systems.

We then analyse the effects of the conversion period on the economic performance of the farms using data from several years of follow-up. Thus, the conversion period is accompanied by a decrease in profitability, but the farms in conversion seem to be more efficient at the beginning than the average of the farms in the sample. Furthermore, the growth of assets in the organic sector may, at least temporarily, reduce their profitability if their income does not grow as fast as their assets. A longer observation period would allow us to have a more complete view of the long-term profitability of organic farms.

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