Farm performance and investment decisions: evidence from the French (Brittany) dairy sector

Loïc LEVI, Laure, LATRUFFE, Aude RIDIER

Working Paper SMART – LERECO N°19-01

Mars 2019

UMR INRA-Agrocampus Ouest **SMART - LERECO**

(Laboratoires d'Etudes et de Recherches en Economie sur les Structures et Marchés Agricoles, Ressources et Territoires)

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Loïc LEVI

INRA, UMR1302 SMART-LERECO, 35000, Rennes, France

Laure LATRUFFE

INRA, UMR1302 SMART-LERECO, 35000, Rennes, France

Aude RIDIER

AGROCAMPUS OUEST, UMR1302 SMART-LERECO, 35000, Rennes, France

Acknowledgements

The authors acknowledge financial support from the Chair 'Enterprises and Agricultural Economics' and the Economic Division (SAE2) of INRA. They are also grateful to CER France Ille-et-Vilaine for providing access to their data, as well as Luc Mangelinck and Geneviève De Lansalut from CER France Ille-et-Vilaine for their advice.

Corresponding author

Aude Ridier
UMR SMART-LERECO
4, allée Adolphe Bobierre
CS 61103
35011 Rennes Cedex, France
Email : aude.ridier @agrocampus-ouest.fr
Téléphone / Phone : +33 (0) 2 23 48 56 92
Fax: +33 (0) 2 23 48 54 17

Investissement et performance : le cas des exploitations laitières bretonnes

Résumé

L'objectif de ce travail est d'analyser le rôle de la performance des exploitations agricoles dans les décisions d'investissement des exploitants, grâce à un modèle théorique prenant en compte les coûts d'ajustement et la performance. Le modèle est estimé sur un échantillon cylindré d'exploitations laitières spécialisées en Bretagne entre 2005 et 2014. Deux types d'exploitations sont considérées : celles avec une forte intensité en capital, et celles avec une faible intensité en capital. Les résultats montrent que répartir l'investissement sur plusieurs années est en moyenne une stratégie optimale pour maintenir la performance lorsqu'il y a des coûts d'ajustement. De plus, l'effet de la performance sur le comportement d'investissement diffère entre les deux types d'exploitations.

Mots-clés : exploitation agricoles laitières, investissement, performance, coûts d'ajustement, France, Bretagne

Classifications JEL: Q12, D92

Farm performance and investment decisions: evidence from the French (Brittany) dairy sector

Abstract

The objective of this paper is to investigate the role of farm performance in farmers' investment decisions with a theoretical model accounting for adjustment costs and performance. The model is estimated on a balanced sample of specialised dairy farms in Brittany (western France) between 2005 and 2014. Two types of farms are considered: with high and with low capital intensity. The results show that spreading investment over time is, on average, an optimal strategy for maintaining performance in the presence of adjustment costs. In addition, the effect of performance on investment behaviour differs between the two farm types.

Keywords: farm investment, performance, adjustment cost model, dairy sector, France

JEL classifications: Q12, D92

Farm performance and investment decisions:
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1. Introduction

Investment helps farmers adapt to changing conditions, such as higher price volatility and policy changes. In recent decades, trade liberalisation and reforms of the European Union's (EU) Common Agricultural Policy (CAP), particularly the 2003 Luxembourg agreement which replaced most of the coupled payments with decoupled ones (the Single Farm Payment – SFP), have resulted in both higher uncertainties for farmers and higher price volatility. In the particular case of dairy farms, one recent major policy change was the ending of milk quotas: the quotas were effectively abolished in 2015, but the reform had been announced as early as 2003 and had then been confirmed in 2008 with a range of measures aimed at achieving a "soft landing". All this strongly impacted farmers' decisions as they needed to adapt in order to remain competitive in such a changeable environment. Dairy farmers in particular may have increased their investment as early as in 2003 so as to be ready as soon as quotas were removed in 2015.

The economic literature has largely studied the determinants of firms' investment behaviour. The main determinants are of *economic* origin and include the output price, the capital price, the output quantity sold, and, by extension, the output quantity produced. In his literature review, Chirinko (1993) pointed out that the quantity of output produced influences a firm's investment behaviour more greatly than capital price does. A second type of determinants are *financial*, namely related to financial constraints and interest rates. For example, Budina et al. (2000) found that, during the period 1993-1995, Bulgarian firms faced high liquidity constraints, and that a firm's size and financial structure contributed to distinguishing between firms that were, or were not, constrained by liquidity. Latruffe (2005) confirmed the presence of rural credit market imperfections in Poland during 1996-2000, in the sense that, for some farms, the only or the least expensive source of funds to cover investment was internal funds. O'Toole et al. (2014) suggested that the Irish farm sector encountered difficulties in accessing credit for investment in productivity-enhancing technology.

A third type of determinants of investment relate to *public policy*; that is, public support, the tax system, standards or regulations. For a sample of Italian specialised arable crop farms during 1994-2002, Sckokai and Moro (2009) found that an increase in the intervention price would significantly affect farm investment, mainly through reduced price volatility. A fourth type of determinants are *structural*, relating to the quasi-fixed nature of assets, irreversibility of investment, sunk costs (Chavas, 1994), and adjustment costs. The adjustment cost theory assumes that farms experience adjustment costs when they invest, such as the cost of extra time or production losses until both farmer and herd become familiar with the new machines and technologies. Bokusheva et al. (2009) showed that the adjustment cost model is adequate for evaluating investment behaviour in the farming sector mainly in the short term, but less satisfactory for explaining long-term decisions. A fifth type of investment determinants are *sociological and psychological factors*. They relate, for example, to farmers' age and education level, and personal attitudes or values.

The sixth determinant type are *organisational* and concern managerial performance and labour productivity. However, there is little literature illustrating the role of organisational drivers. In theory, the effect of farm performance on investment is ambiguous. On the one hand, high farm performance can allow farmers to afford investment in the future, in line with the accelerator effect; on the other hand, farmers with a highly performing farm may postpone investment in order to avoid adjustment costs that would decrease their performance in the short term. In addition, when accounting for farm performance in investment decisions, endogeneity has to be controlled for: performance not only influences investment decisions, but investment decisions also influence performance. Indeed, in the literature, several authors have shown that farm performance is influenced by investment (Sauer and Latacz-Lohmann, 2015; Zhengfei and Oude Lansink, 2006). Sauer and Latacz-Lohmann (2015) showed that, for dairy farms in Germany for the period 1995-2010, investment in innovative technology allowed performance (measured by the productivity of dairy production) to be increased. Zhengfei and Oude Lansink (2006) showed that, for Dutch cash crop farms over the period 1990-1999, investment, proxied by the level of debt, had no significant effect on global financial performance (measured by the return on equity), whereas it had a positive effect on productivity growth. However, although the endogeneity of performance and investment variables is sometimes recognised and controlled for (Zhengfei and Oude Lansink, 2006), explicit investigation of the effect of current performance on future investment decisions, accounting for endogeneity, has never been performed. This question is of particular interest in the case of dairy farming in the context of the ending of milk quotas. What kind of structural changes can be expected from this policy change? In other words, will farms that are already highly performing invest even more and expand or will they be slowed down by adjustment costs?

In this context, the objective of this paper is to investigate the effect of current performance on future investment decisions for the particular case of the dairy sector. Our study is applied to a sample of specialised dairy farms in the French western region of Brittany during the 2005-2014 period. The adjustment cost model is used with performance being introduced in the modelling strategy, accounting for endogeneity, as well as for farm heterogeneity through different farm capital intensities. Indeed, we consider two types of farms that may have different investment strategies: farms that have a high capital intensity, and farms that have a low capital intensity. The investment behaviour of these farm types may differ for several reasons. Farms may differ in their current performance, which may differently affect future investment decisions; the impact of adjustment costs on investment decisions may also depend on the initial capital endowment.

The article is structured as follows. Section 2 develops the underlying theoretical framework that guides the econometric estimations. Section 3 describes the database and explains the econometric specification. Section 4 presents the results while Section 5 concludes.

2. Theoretical framework

In this section, we develop a simple theoretical framework that supports the empirical model that will be estimated. To study farmers' investment decisions accounting for the link with farm performance, we use an adjustment cost model. Contrary to the ad hoc accelerator model, the adjustment cost model provides a consistent theoretical basis for explaining agricultural investment patterns in the context of dynamically optimising economic agents. Adjustment cost theory has been the main approach used in the literature on investment to explain why firms partially adapt their capital stock to the optimal level (Bond and Meghir, 1994; Hubbard and Kashyap, 1992; Lizal and Svejnar, 2002; Rizov, 2004). According to this theory, firms undergo a short-run loss in output or profit when they modify their stocks of quasi-fixed production factors due to adjustment costs. These costs arise from actions aimed at ensuring frictionless flow (maintenance), and may include gradual adjustments (refinements and improvements that require necessitating training) or more substantial adjustments (Caballero, 1999). In the firms' profit maximising framework, the adjustment cost hypothesis is formalised by including investment as an argument in the profit function. The adjustment cost model is particularly relevant for the agricultural sector due to the existence of asset fixity, especially in the livestock sector, as Galbraith and Black (1938) argued many decades ago. Farms' fixed production factors are lumpy, implying that their reduction or reorganisation is costly. This explains why farms may be unprofitable in the short run.

The theoretical framework assumes that dairy farmers are risk neutral and maximise the expected net present value of their profits in period *t* over an infinite horizon:

$$Max\ E_t\ \{\sum_{t=0}^{\infty} \beta_t \pi_t\{K_t, I_t, X_t\}\} \tag{1}$$

on K_t, I_t, X_t

subject to

$$K_t = (1-\delta)K_{t-1} + I_t \tag{2}$$

$$\pi_t\{K_t, I_t, X_t\} \geq 0 \tag{3}$$

where subscript *t* refers to the *t*-th period; farm capital K_t is a stock variable and investment I_t is a flow variable; X_t is the level of variable inputs used on the farm; β is the discount factor; δ is the depreciation rate; E_t is the expectation operator conditional on information available to the farmer at the start of period *t*, expectations being taken over future prices and technologies (Bond and Meghir, 1994). For simplicity, the farm subscript *i* is dropped from all variables.

Equation (2) represents capital accumulation, in the sense that the current capital stock consists of last year's capital stock, adjusted for depreciation at rate δ, plus current investment. Equation (3) is a non-negativity constraint that ensures that the farm profit is positive in each period.

The Lagrangian function can be written as follows:

$$\begin{aligned} \mathrm{L} = E_t\{\textstyle\sum_{t=0}^{\infty} \beta_t \pi_t\{K_t, I_t, X_t\}\} + \cdots + \lambda_t[I_t - K_t + (1-\delta)K_{t-1}] + \lambda_{t+1}[I_{t+1} - K_{t+1} + \\ + (1-\delta)K_t] + \cdots + \mu_t[\pi_t\{K_t, I_t, X_t\}] + \mu_{t+1}[\pi_{t+1}\{K_{t+1}, I_{t+1}, X_{t+1}\}] \end{aligned} \tag{4}$$

where λ_t and μ_t are the Lagrangian multipliers associated with constraints (2) and (3) respectively.

The first order conditions for investment I_t and capital K_t respectively are as follows:

$$\frac{\partial L}{\partial I_t} = E_t\left\{(\beta_t + \mu_t)\frac{\partial \pi_t}{\partial I_t}\right\} + \lambda_t = 0 \tag{5}$$

$$\frac{\partial L}{\partial K_t} = E_t\left\{(\beta_t + \mu_t)\frac{\partial \pi_t}{\partial K_t}\right\} - \lambda_t + \lambda_{t+1}(1-\delta) = 0 \tag{6}$$

Combining these two first order conditions yields:

$$E_t\left\{(\beta_t + \mu_t)\frac{\partial \pi_t}{\partial I_t}\right\} + E_t\left\{(\beta_t + \mu_t)\frac{\partial \pi_t}{\partial K_t}\right\} - (1-\delta)E_t\left\{(\beta_{t+1} + \mu_{t+1})\frac{\partial \pi_{t+1}}{\partial I_{t+1}}\right\} = 0 \tag{7}$$

Following this, the Euler equation defining the optimal investment path can be derived (eq. 8). We assume here rational expectations (Muth, 1961), implying that the expected value in period t-1 is equal to the value in period t corrected with an error term:

$$E_t\left\{\frac{\partial \pi_t}{\partial I_t}\right\} - (1-\delta)\frac{(\beta_{t+1}+\mu_{t+1})}{(\beta_t+\mu_t)}E_t\left\{\frac{\partial \pi_{t+1}}{\partial I_{t+1}}\right\} + E_t\left\{\frac{\partial \pi_t}{\partial K_t}\right\} = \varepsilon_{t+1} \quad (8)$$

where ε_{t+1} is an error term that is assumed to be uncorrelated with the explanatory variables.

The profit function at time t is specified as follows:

$$\pi_t\{K_t, I_t, X_t\} = p_t Y_t - C_t - w_t X_t - p_t^I I_t \quad (9)$$

where p_t is the output price; Y_t is the output produced; C_t are adjustment costs; w_t is the variable input price and p_t^I is the investment price.

Our contribution is to model the link between performance and investment decisions. For this, we assume that the output not only depends on the production factors (fixed and variable inputs), but also on a performance parameter designated u_t (eq. 10), which could be viewed as the farmer's managerial ability (Galanopoulos et al., 2006; Ondersteijn et al., 2003; Solano et al., 2006):

$$Y_t = f(K_t, X_t, u_t) \quad (10)$$

The production function f is assumed to be quadratic and to increase with performance.

Our further contribution is to assume that performance depends on capital stock, capturing size effects:

$$u_t = g(K_t) \quad (11)$$

However, no specific assumption is made about the sign of the first derivative of the performance function g with respect to capital, that is, about the sign of scalar b in equation (12). The derivative may be either negative or positive. If negative, it means that farmers operating farms with larger capital would have a lower performance than farmers operating farms with smaller capital. If positive, it indicates that farmers on farms with larger capital would have a higher performance than those operating farms with smaller capital. It is assumed that the effect of capital size on performance depends on the level of performance itself (eq. 12), so that the effect is amplified at high levels of performance:

$$\frac{\partial g(K_t)}{\partial K_t} = b u_t \quad (12)$$

The first derivatives of the production function with respect to capital and to performance are:

$$\frac{\partial f(Y_t)}{\partial K_t} = \alpha_0 + \alpha_1 K_t + \alpha_2 X_t + \alpha_3 u_t \quad > 0 \tag{13}$$

$$\frac{\partial f(Y_t)}{\partial u_t} = a > 0 \tag{14}$$

Equation (13) shows that the derivative with respect to capital is assumed to be positive, meaning that output increases when capital increases, but no assumption is made on the sign of the parameters $\alpha_0, \alpha_1, \alpha_2,$ and α_3. Equation (14) represents the intuitive idea that the higher the farmer's performance, the higher the output produced.

As is standard in the literature, the adjustment costs incurred by farms are assumed to be quadratic and to depend on K_t and I_t through a function h (eq. 15), whose derivative with respect to investment increases with investment and whose derivative with respect to capital depends on investment squared:

$$C_t = h(K_t, I_t) \tag{15}$$

$$\frac{\partial h(K_t, I_t)}{\partial I_t} = \theta_0 + \theta_1 I_t \qquad \text{with } \theta_1 > 0 \tag{16}$$

$$\frac{\partial h(K_t, I_t)}{\partial K_t} = \gamma_0 + \gamma_1 {I_t}^2 \tag{17}$$

Using equations (9), (10) and (15), the Euler equation (8) can then be rewritten as follows:

$$\frac{\partial \pi_t}{\partial C_t}\frac{\partial C_t}{\partial I_t} - p_t^I - (1-\delta)\frac{(\beta_{t+1}+\mu_{t+1})}{(\beta_t+\mu_t)}\left(\frac{\partial \pi_{t+1}}{\partial C_{t+1}}\frac{\partial C_{t+1}}{\partial I_{t+1}} - p_{t+1}^I\right) + \frac{\partial \pi_t}{\partial Y_t}\frac{\partial Y_t}{\partial K_t} - \frac{\partial \pi_t}{\partial C_t}\frac{\partial C_t}{\partial K_t} = \varepsilon_{t+1} \tag{18}$$

Furthermore, using equations (12), (13), (14), (16), (17), it can be rewritten as:

$$-(\theta_0 + \theta_1 I_t) - p_t^I - (1-\delta)\frac{(\beta_{t+1}+\mu_{t+1})}{(\beta_t+\mu_t)}\left(-(\theta_0 + \theta_1 I_{t+1}) - p_{t+1}^I\right) +$$
$$+ p_t(\alpha_0 + \alpha_1 K_t + \alpha_2 X_t + \alpha_3 u_t) - \left(\gamma_0 + \gamma_1 {I_t}^2\right) = \varepsilon_{t+1} \tag{19}$$

Assuming that the price of investment (p_t^I) is constant across farms and years, the final model is:

$$I_{t+1} = \vartheta_0 + \vartheta_1 I_t + \vartheta_2 {I_t}^2 + \vartheta_3 u_t p_t + \vartheta_4 X_t p_t + \vartheta_5 K_t p_t + \vartheta_6 p_t + \varepsilon_{t+1} \tag{20}$$

with:

$$\vartheta_1 = \frac{(\beta_t+\mu_t)}{(1-\delta)(\beta_{t+1}+\mu_{t+1})} > 0 \tag{21}$$

$$\vartheta_2 = \frac{\gamma_1}{\theta_1}\frac{(\beta_t+\mu_t)}{(1-\delta)(\beta_{t+1}+\mu_{t+1})} \tag{22}$$

$$\vartheta_3 = -\frac{\alpha_3}{\theta_1}\frac{(\beta_t+\mu_t)}{(1-\delta)(\beta_{t+1}+\mu_{t+1})} \tag{23}$$

$$\vartheta_4 = -\frac{\alpha_2}{\theta_1}\frac{(\beta_t+\mu_t)}{(1-\delta)(\beta_{t+1}+\mu_{t+1})} \tag{24}$$

$$\vartheta_5 = -\frac{\alpha_1}{\theta_1}\frac{(\beta_t+\mu_t)}{(1-\delta)(\beta_{t+1}+\mu_{t+1})} \tag{25}$$

$$\vartheta_6 = -\frac{\alpha_0}{\theta_1}\frac{(\beta_t+\mu_t)}{(1-\delta)(\beta_{t+1}+\mu_{t+1})} \tag{26}$$

Equation (21) shows that ϑ_1 is positive, and hence a positive impact of I_t on I_{t+1} is expected in equation (20). As θ_1 and $\frac{(\beta_t+\mu_t)}{(1-\delta)(\beta_{t+1}+\mu_{t+1})}$ are assumed to be positive, the direction of the impact of ${I_t}^2$ on I_{t+1} (i.e. the sign of ϑ_2, eq. 22) gives an indication of the sign of γ_1, that is on the shape of the adjustment cost function in equation (17). The sign of ϑ_3 (eq. 23), related to the effect of $u_t p_t$ on I_{t+1}, gives an indication of the sign of α_3, that is the direction of the impact of performance u_t on the marginal productivity of K_t in equation (13). The sign of ϑ_4 (eq. 24), reflecting the effect of $X_t p_t$ on I_{t+1}, gives an indication of the sign of α_2, namely the effect of X_t on the marginal productivity of K_t. The direction of the impact of $K_t p_t$ on I_{t+1} (ϑ_5, eq. 25) gives an indication of the sign of α_1, namely on the effect of K_t on the marginal productivity of K_t.

3. Data and econometric specification

The data set used here includes accountancy information for a fully balanced sample of 661 specialised dairy farms in one sub-region (*département*) of Brittany (namely Ille-et-Vilaine, with main town Rennes) provided by a regional private accounting office,[1] covering the period 2005-2014. Hence, the pooled sample for the ten years includes 6,610 observations.

Capital (K_t) is proxied by the net value of fixed assets, including all tangible assets such as buildings, machinery and equipment, breeding livestock and land. Investment (I_t) is net investment computed as the difference between periods *t* and *t*-1 of the net capital.[2] The output price (p_t) is the milk sale price in period *t*[3], milk being the main output for this farm sample.

[1] CER FRANCE Ille-et-Vilaine. This accounting office manages the accounts of the majority of farmers in Brittany.

[2] Values of capital and investment in period *t* were deflated by the price index of the means for agricultural production and more precisely the price index of investment goods with base year 2010.

[3] The milk sale price was deflated by the price index of agricultural products with base year 2010.

The variable input (X_t) is proxied by operational expenses,[4] i.e. the costs related to the farming operations, including: costs for purchased animal feed, produced forage, straw litter, and fuel; veterinary and animal reproduction costs; costs of temporary labour.

As a proxy for managerial performance (u_t), we use the farm's current value of Earnings Before Interest, Taxes, Depreciation, and Amortisation (EBITDA)[5] in period t divided by the number of total (i.e. family and hired) labour units on the farm in the same period. EBITDA is an indicator of the operating profitability of a farm since it measures the potential cash flow obtained from the farming activity and is used to remunerate the farm labour. It can, thus, be seen as a proxy for the farmer's managerial ability, which influences the generated farm output. Relating the EBITDA to labour controls for farm size. A high EBITDA per labour unit at the end of period t reveals that the farmer has been performing highly in this period, and thus is a good proxy for high u_t.

As shown in Table 1, during the period considered, farms in the sample on average operated 77 hectares (ha) of utilised agricultural area (UAA), used 2 full-time equivalent labour units, and bred 52 dairy cows producing 7,155 liters of milk per cow. Table 1 also shows that farms in our sample are larger, on average, than those from the exhaustive Agricultural Census population of the same sub-region in terms of UAA and labour use, but similar in terms of number of cows, and have a higher milk yield. Our sample probably includes farms with a stronger commercial character (and a greater likelihood to use bookkeeping), which are the ones that would be most greatly impacted by the end of the quotas.

Figure 1 displays, for our sample, the evolution of the yearly average level of investment and of milk price over the considered period. Total investment increases up to 2009, drops in 2010 and 2011, and increases again afterwards. The investment increase in 2008-2009 may be due to the significant milk price increase in 2007-2008, which was followed by a significant decrease in 2010, after the beginning of the economic crisis. In 2009, the dairy sector experienced a deep crisis in the form of a sudden milk price decrease, while input prices remained at a high level.

[4] These were deflated by the price index of the means for agricultural production and more precisely the price index of goods and services consumed in agriculture with base year 2010.

[5] The EBITDA were deflated by the price index of agricultural products with base year 2010.

Table 1. Descriptive statistics of the sample used and comparison with the Agricultural Census population

	Sample used	Total farm population in the same sub-region as our sample
	(Sample average over 2005-2014)	(Population average in 2010; Agricultural Census)
Structural variables		
Milk produced (liters)	376,251	356,110
UAA (ha)	77	63
Number of dairy cows	52	52
Number of labour full-time equivalent units	2.0	1.7
Milk yield (liters / cow)	7,155	7,036
Number of observations	661	3,248

Source: Authors' computations based on CER FRANCE Ille-et-Vilaine and Agreste (2010.

Figure 1: Evolution of the average level of investment and milk price for the sample used between

Source: The authors, based on CER FRANCE Ille-et-Vilaine

Table 2. Descriptive statistics of the main variables of interest for the sample used

Variables used in estimation	Mean	Std. Dev.	Min	Max	Number of observations
I_t/K_t	-0.0074	0.15	-1.36	0.85	5,949
I_t^2/K_t	7,097	25,287	0.00	1,107,676	5,949
u_tP_t/K_t (per 1,000 liters)	62	43	-80	1,223	6,610
X_tP_t/K_t (per 1,000 liters)	140	86	11	796	6,610
P_t/K_t (per 1,000 liters)	1.72e-03	1.09e-03	1.93e-04	13.4e-03	6,610
Variables in levels					
Investment (I_t) (€)	3,270	55,070	-333,685	1,467,339	5,949
Output price (P_t) (€ per 1,000 liters)	327	33	252	483	6,610
Variable inputs (X_t) (€)	103,309	84,217	5,352	1,102,166	6,610
Capital (K_t) (€)	256,678	152,203	23,411	1,943,785	6,610
EBITDA (€)	77,908	46,094	-11,312	539,760	6,610
EBITDA per labour unit (u_t) (€)	39,458	17,458	-11,312	221,829	6,610

Source: The authors, based on CER FRANCE Ille-et-Vilaine

Table 2 provides summary statistics for the key variables included in the model. On average, the level of investment over the period is €3,270 per farm in our sample. The standard deviation is high, indicating high heterogeneity in investment behaviour across farms and years. Over the period considered, the annual percentage of zero and negative investment values is, on average, 58 percent (i.e. 42 percent for positive investment values) and increases significantly from 2011 onwards (not shown in Table 2). Output price is on average €327 per 1,000 liters. Variable input cost is on average €103,309 and the ratio of variable input (X_t) to output (Y_t) is about 0.48, with a high standard deviation (0.10) revealing high heterogeneity in the technology relating to the cost of concentrates and of forage. The performance ratio (u_t) is on average €39,458 per labour unit, which is relatively high but again hides a large heterogeneity across farms, as shown by the high standard deviation.

The heterogeneity revealed by Table 2 indicates heterogeneous technologies within the sample, notably in terms of capital and variable inputs. Such technological heterogeneity may imply differing adjustment costs, and hence differing investment strategies and impact of performance. For this reason, firstly equation (27) is estimated, and then an augmented version of equation (27) is estimated, namely with interaction effects; that is, with each explanatory variable interacted with a dummy variable capturing the farms' capital intensity. Using Hierarchical Ascendant Classification (HAC) with Ward's method, a cluster analysis is firstly performed in order to identify the groups of farms with similar capital intensity. We separate farms into different groups based on the following specific characteristics: the herd size (i.e. number of dairy cows); the share of fodder maize in the farm forage area; the stocking rate (i.e. number of Livestock Units[6] per hectare, LU/ha); the cost of work outsourcing per LU; the cost of concentrates per dairy cow; and the capital per LU. In order to distinguish farms based on their average structure during the period, as well as on their evolution over time, we use two types of variables: *static*, namely the average value over the whole period for each characteristic listed above, and *dynamic*, namely the 2005-2014 growth rate of each characteristic, except the growth rate of the cost of work outsourcing which is strongly correlated with other variables.

The HAC identifies two clusters of farms in our sample (Tables 3 and 4). For these two clusters, Table 3 reports descriptive statistics of the variables used for the classification, while Table 4 presents descriptive statistics of additional farm characteristics. On average, compared to farms in cluster 2 (239 farms), farms in cluster 1 (422 farms) exhibit significantly larger size in terms of number of dairy cows (55 vs. 48), are more intensive with a higher share of fodder maize in forage area (46 vs. 37 percent), stocking rate (1.68 vs 1.62 LU/ha) and concentrates cost per dairy cow (€402 vs. 224), and have higher costs of work outsourcing per LU (€1.84 vs. 1.52). Likewise, farms in cluster 1 experienced a higher rate of growth in the number of dairy cows (0.35 vs. 0.22) and stocking rate (0.06 vs. 0.01) between 2005 and 2014. This suggests that, on average, farms in cluster 1 are more capital intensive than farms in cluster 2. Thus, in what follows farms in cluster 1 are called farms with "high capital intensity", while farms in cluster 2 are called farms with "low capital intensity".

[6] Livestock Units (LU) allow the aggregation of the number of livestock heads from different types of animals, here dairy heifers, calves and dairy cows. Each type of animal is assigned a coefficient depending on its feed consumption.

Table 3. Descriptive statistics of the variables used in the hierarchical ascendant classification analysis for the two clusters identified

	Cluster 1 High capital intensive farms (422 farms)	Cluster 2 Low capital intensive farms (239 farms)	t-test (equality of means)
Average over 2005-2014 (*standard deviation*)			
Number of dairy cows	55 (18)	48 (18)	***
Share of fodder maize in forage area (percent)	46 (14)	37 (14)	***
Stocking rate (LU / ha)	1.68 (0.28)	1.62 (0.28)	***
Cost of work outsourcing per LU (€)	1.84 (0.73)	1.52 (0.79)	***
Concentrates cost per dairy cow (€)	402 (88)	224 (55)	***
Capital stock per LU (€)	79 (36)	67 (26)	***
Rate of growth 2005-2014 (*standard deviation*)			
Number of dairy cows	0.35 (0.32)	0.22 (0.22)	***
Share of fodder maize in forage area	-0.12 (0.97)	-0.17 (0.78)	**
Stocking rate	0.06 (0.21)	0.01 (0.15)	***
Concentrates cost per dairy cow	0.64 (0.55)	0.75 (1.17)	***
Capital stock per LU	0.21 (0.37)	0.22 (0.36)	
Number of dairy cows	0.35 (0.32)	0.22 (0.22)	***

*Notes: The rate of growth is computed as the difference between the value in 2014 and the value in 2005, divided by the value in 2005. *, **, ***: significance at the 10, 5, 1 percent level.*

Source: The authors, based on CER FRANCE Ille-et-Vilaine

Table 4. Descriptive statistics of additional characteristics of the clusters

	Cluster 1 High capital intensive farms	Cluster 2 Low capital intensive farms	Cluster 1 High capital intensive farms	Cluster 2 Low capital intensive farms
Technical variables	Average in 2005 (*standard deviation*)		Average in 2014 (*standard deviation*)	
Number of full time equivalent labour units	2.1 (0.84)	1.8 (1.04)	2.1 (0.83)	1.7 (1.14)
UAA (ha)	76 (34)	61 (31)	89 (43)	68 (34)
Total milk produced (liters)	355,350 (137,390)	266,916 (127,128)	508,786 (197,646)	346,466 (167,383)
Milk yield (liters / cow)	7,375 (989)	6,076 (1,156)	7,962 (1,110)	6,475 (1,230)
Financial variables	Average in 2005 (*standard deviation*)		Average in 2014 (*standard deviation*)	
EBITDA (€)	87,022 (44,120)	65,922 (41,644)	90,770 (47,573)	65,112 (43,527)
EBITDA (€ / 1,000 liters)	169 (103)	195 (110)	124 (54)	146 (69)
EBITDA / Full time equivalent labour unit (€)	41,994 (16,584)	37,636 (16,625)	43,312 (18,318)	39,227 (21,769)
Current income (€)	10,913 (22,613)	13,097 (20,683)	17,708 (26,716)	18,344 (20,991)
Indebtedness (percent)	51.6 (20)	46.7 (22)	50.8 (20)	42.8 (21)
Number of observations	422	239	422	239

*Notes: The rate of growth is computed as the difference between the value in 2014 and the value in 2005, divided by the value in 2005. *, **, ***: significance at the 10, 5, 1 percent level.*

Source: The authors, based on CER FRANCE Ille-et-Vilaine

4. Results

4.1. Estimation results for the full sample

Table 5 shows the results of the estimation of the investment model presented in equation (27) (column A) and of the augmented version of it with interaction effects (column B). The results of the estimation of equation (27) (column A) indicate that the model is highly significant, as shown by the Wald test. We employ the generalised method of moments (GMM) (Arellano and Bond, 1991; Arellano and Bover, 1995) as it allows account for two sources of potential endogeneity. Also, the Sargan test of over-identifying restrictions does not reject the null hypothesis of the validity of instruments at the 10 percent level of significance.

Three main findings can be noted from Table 5. Firstly, the coefficient for the investment to capital at period *t* (ϑ_1) is significant and positive, while the coefficient for the square of the investment to capital at period *t* (ϑ_2) is significant and negative. This indicates that higher investment in period *t* increases investment in *t*+1, consistent with the underlying theoretical framework and suggesting that farmers smooth their investment over time in order to undergo the lowest adjustment costs. These adjustment costs are captured by the negative value of ϑ_2, implying a negative value for γ_1 (see eq. 22), showing the marginal cost of having a higher level of capital in the profit function. All this reveals that the adjustment cost model is an adequate framework for our sample.

Secondly, the coefficient for the variable including the performance indicator, $\frac{u_{i,t}p_{i,t}}{K_{i,t}}$, (ϑ_3) is non-significant. This suggests that, for a given (positive) price, there is no effect of performance in period *t* on investment in *t*+1 on average for the full sample. We investigate this further in the next sub-section with the separation of farms across the clusters of capital intensity.

Thirdly, as expected, the average effect of price in period *t* on investment to capital in period *t*+1 is positive. For each farm *i* in each period *t*, the full effect of price is obtained by deriving equation (27) with respect to $p_{i,t}$, yielding:

$$\frac{\partial(\frac{I_{i,t+1}}{K_{i,t}})}{\partial P_t} = \vartheta_3 \frac{u_{i,t}}{K_{i,t}} + \vartheta_4 \frac{X_{i,t}}{K_{i,t}} + \vartheta_5 + \vartheta_6 \frac{1}{K_{i,t}} \quad (28)$$

The individual values are then averaged over the farms and over the years to provide a sample's average. The latter is presented in the first row of Table 6. For the whole sample, the average full price effect is 0.46, suggesting that when the milk price increases by one € per 1,000 liters, the ratio of investment to capital in period *t*+1 increases by 0.46. Likewise, it decreases by 0.46 when the milk price decreases by one € per 1,000 liters. This positive effect is conform to theory and reveals that higher sale opportunities give incentives to farmers to expand, and thus to invest. The evolution of the average price effect over time (see Figure 2) shows lower effects from 2012 onwards, revealing weaker price incentives in this period.

4.2. Estimation results for farm groups based on their capital intensity

As seen above, on average for the full sample there is no significant effect of performance on investment, and this may be the result of heterogeneous behaviour within the sample, which could already be seen from the sample's descriptive statistics. For this reason, we separated the farms into two groups based on their capital intensity with the help of HAC. To investigate whether the two groups have a different strategy in terms of investment, we estimate an augmented version of equation (27) with interaction terms. More precisely, we interact all explanatory variables with a dummy variable taking the value one for farms with high capital intensity and zero for farms with low capital intensity.

The last column of Table 5 reports the results of the estimation of this interaction investment model, where the reference groups are low capital intensive farms. Hence, the coefficients for this reference group are those for the variables without interaction (i.e. when the dummy equals zero), while a coefficient for the high capital intensive farms is obtained by adding the coefficient for the variable without interaction and the coefficient for the variable with interaction. For example, the coefficient for the investment to capital ratio in period *t* is 0.717 (ϑ_1) for low capital intensive farms, while the coefficient for high capital intensive farms is obtained by adding 0.717 and -0.944, which gives the value -0.227.

Three main findings can be noted. Firstly, the coefficient for the investment-to-capital ratio in period t is positive for low capital intensive farms, but negative for high capital intensive farms, while the coefficient for the square of investment to capital in period t is negative for both groups. While the latter result reveals that both groups of farms undergo adjustment costs, the result regarding the investment-to-capital ratio confirms the presence of such costs (through a behaviour of smoothing investment over time) for low capital intensive farms only. By contrast, high capital intensive farms decrease their investment in period *t*+1 when they have already implemented high investment in period *t*.

Secondly, the coefficient for the performance variable $\frac{u_{i,t}p_{i,t}}{K_{i,t}}$ (ϑ_3) is negative for high capital intensity farms and positive for low capital intensity farms. This suggests that high capital intensive farms face the above-mentioned trade-off between investing now to increase their size and hence their performance, or postponing investment in order to avoid a decrease in performance in the following year due to adjustment costs. This may also explain the above-mentioned finding that high capital intensive farms, having invested in the current period, decrease their investment in the next period in order to maintain their performance level.

On the contrary, during the studied period, a high performance in period *t* encouraged farms in the low capital intensive group to invest in *t*+1 (positive coefficient ϑ_1) in order to increase their size and hence their performance. This may be explained by the removal of quotas which was progressively implemented. Between 2008 and 2015, the dairy quota allocation increased progressively to achieve a “soft landing”, creating new opportunities for the dairy sector in Brittany to take advantage of the increasing global demand for dairy products even before the effective removal of quotas. Our results suggest that low capital intensive farms used these opportunities in contrast to high intensive farms.

Thirdly, on average, the effect of price in period *t* on investment to capital in period *t*+1 is much smaller for low capital intensive farms (0.03) than for high capital intensive farms (0.84) (Table 6). This discrepancy might suggest that low capital intensive farms need to invest to be able to cope with the new economic conditions, when quotas are effectively removed, and that they should do so regardless of the price level.

Table 5. Results of the estimation of the investment model for the whole sample and with interaction terms: estimated coefficients

	Dependent variable: investment per capital in t+1	
	A	B
Intercept	-0.103*** (0.0386)	-0.0836** (0.0359)
$\vartheta_1 \left(I_{i,t} / K_{i,t} \right)$	0.217*** (0.0437)	0.717*** (0.0656)
$\vartheta_1 \left(I_{i,t} / K_{i,t} \right) \times dummy$ high capital intensive farms		-0.944*** (0.0883)
$\vartheta_2 \left({I_{i,t}}^2 / K_{i,t} \right)$	-3.59e-06*** (6.43e-07)	-9.47e-06*** (1.21e-06)
$\vartheta_2 \left({I_{i,t}}^2 / K_{i,t} \right) \times dummy$ high capital intensive farms		4.98e-06*** (1.23e-06)
$\vartheta_3 \left(u_{i,t} P_{i,t} / K_{i,t} \right)$	0.0870 (0.283)	1.010** (0.446)
$\vartheta_3 \left(u_{i,t} P_{i,t} / K_{i,t} \right) \times dummy$ high capital intensive farms		-1.147** (0.483)
$\vartheta_4 \left(X_{i,t} P_{i,t} / K_{i,t} \right)$	1.160*** (0.207)	0.988*** (0.354)
$\vartheta_4 \left(X_{i,t} P_{i,t} / K_{i,t} \right) \times dummy$ high capital intensive farms		0.0189 (0.407)
$\vartheta_5 \left(P_{i,t} \right)$	-2.403*** (0.168)	-3.559*** (0.318)
$\vartheta_5 \left(P_{i,t} \right) \times dummy$ high capital intensive farms		1.645*** (0.396)
$\vartheta_6 \left(P_{i,t} / K_{i,t} \right)$	447.759*** (35.416)	487.389*** (60.575)
$\vartheta_6 \left(P_{i,t} / K_{i,t} \right) \times dummy$ high capital intensive farms		-45.408 (72.201)
Number of farms	661	661
Wald Chi2	591.83***	787.06***
Sargan test: p-value	0.0563	0.1716
Instruments: lagged variables in period	t-2	t-2

*Notes: Robust standard errors in parentheses. *, **, ***: significance at the 10, 5, 1 percent level.*

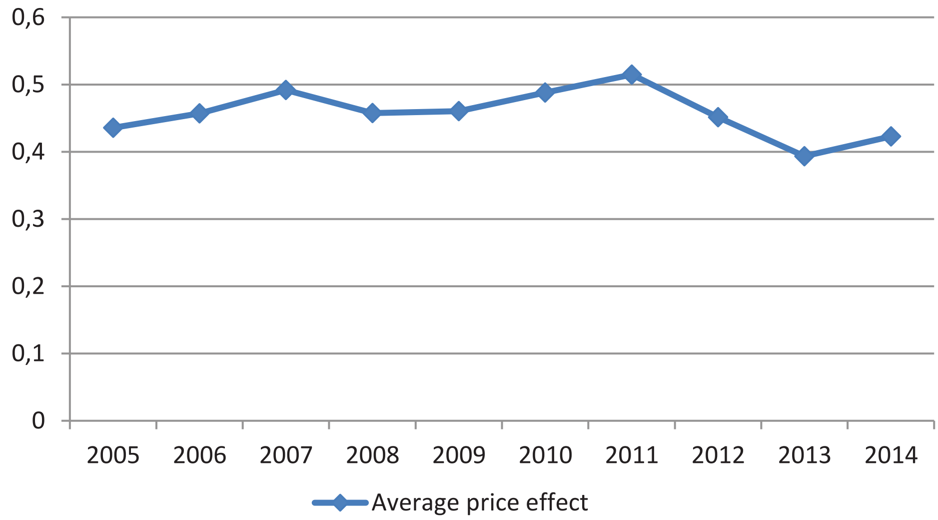
Source: The authors, based on CER FRANCE Ille-et-Vilaine

Table 6. Average full price (in period *t*) effect on investment per capital in *t*+1

Variables used in estimation	Number of observations	Mean	Std. Dev.	Min	Max
Whole sample	6,610	0.46	1.61	-1.99	17.68
High capital intensive farms sub-sample	4,220	0.84	1.45	-1.52	15.05
Low capital intensive farms sub-sample	2,390	0.03	2.14	-2.79	19.80

Source: The authors, based on CER FRANCE Ille-et-Vilaine

Figure 2. Evolution of the average full price (in period *t*) effect on investment per capital in *t*+1 in the full sample between 2005 and 2014



Source: The authors, based on CER FRANCE Ille-et-Vilaine

5. Conclusion

This article provides a new perspective on investment decisions in the dairy farm sector taking into account: i) the link between farm investment and farm performance; and ii) farmers' different investment strategies depending on the level of their farm capital intensity. To do this, the effect of current farm performance on future investment decisions in the dairy sector in a sub-region of Brittany (western France) is investigated over the 2005-2014 period, using an adjustment cost model and including farm performance in the modelling strategy. The model is also estimated in an augmented version, namely with interaction terms that capture both groups of farms identified with HAC: high capital intensive farms, and low capital intensive farms.

Firstly, results show that smoothing farm investment over time is, on average, an optimal strategy in the presence of adjustment costs, as for example reported by Gardebroek and Oude

Lansink (2004). Secondly, on average, it is the high price perspectives that give farmers incentives to invest, rather than their farm performance. Thirdly, the influence of performance on farm investment differs between high capital intensive farms and low capital intensive farms. High capital intensive farms may prefer not to invest in order to avoid adjustment costs in the short term, while low capital intensive farms seem to invest throughout the period regardless of both their performance and milk prices. The investment strategy of the latter might be linked to a strategy of expanding or of increasing milk productivity in the prospect of the removal of dairy quota that occurred after our period of study (namely in 2015) but announced as early as in 2008. This may reveal a standardisation trend in terms of technology in this specialised dairy region. Our findings highlight that farmers' heterogeneity needs to be accounted for in modelling investment behaviour. It allows differentiated strategies to be revealed and can help design targeted policies aimed at encouraging investment, in particular in the context of production quota removal.

We should note here some limitations to our analysis. Our objective was to investigate how performance was linked to farms' investment decisions. In order to limit the complexity of the modelling framework and of econometric estimations, we deliberately made some simplification assumptions. Firstly, we assumed that farmers were risk neutral, although some literature has shown that some farmers are risk averse (Liu, 2013; Young, 1979). Introducing risk in the modelling strategy is hence one avenue for future research. Secondly, we modelled rational expectations, but the literature on investment has highlighted that farmers may have other types of expectations (Thijssen, 1996; Chavas, 1999). Finally, here we proceeded in two steps, separating farms into two clusters in the first step and investigating each cluster's investment decisions in the second step. A more efficient way may be to estimate simultaneously a latent class model and the investment model. Alvarez and del Corral (2010) estimated a latent class model and a stochastic frontier model simultaneously to assess the technical efficiency of more and less intensive farms, and this approach may be developed for future research on investment decisions accounting for farm heterogeneity. A further research avenue is to apply regime-switching models to account for the fact that farms may, or may not, remain in the same capital intensity cluster during the whole period.

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