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# The role of farm performance on investment decisions: evidence from the French (Brittany) dairy sector

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## Abstract

The objective of this paper is to investigate the role of farm performance on investment decisions by estimating an adjustment cost model including explicitly farm performance on a panel sample of specialised dairy farms in Brittany (western France) between 2005 and 2014. Two types of farms are considered: one with high capital intensity and the other with low capital intensity. The results show that spreading investment over time is, on average, an optimal strategy to maintain performance in the presence of adjustment costs. It is the high price perspectives that give incentives to farmers to invest rather than their performance. In addition, the effect of performance on investment behaviour differs between both farm types.

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

**JEL classification:** D22, D24, D92, Q12

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# 1 Introduction

Investment helps farms adapt to changing conditions such as higher price volatility and policy changes. In the past decades, trade liberalization and reforms of the Common Agricultural Policy (CAP), particularly the 2003 Luxembourg agreement which has replaced most of the coupled payments by decoupled ones (the Single Farm Payment – SFP), have resulted in higher uncertainties for farmers and in higher prices' volatility, impacting farmers' decisions. In this context, farmers need to adapt so as to remain competitive. Besides optimizing existing production capacities, investment is key for a competitive and economically sustainable agricultural production. In the particular case of dairy farms, one recent major change is the end of milk quotas: in place in 2015, it had been announced in 2003 and reconfirmed in 2008 with a range of measures aimed at achieving a "soft landing". Dairy farmers may have increased their investments as early as 2003 so as to be ready in 2015.

The economic literature has largely studied the determinants of firms' investment behaviour. The main ones are economic and relate to the output price, the capital price and the output quantity produced. In his literature review, Chirinko (1993) pointed out that the quantity of output produced influences more firms' investment behaviour than capital price does. A second type of determinants are financial (financial constraint, interest rate). For example, Budina et al. (2000) found that Bulgarian firms for the period 1993-1995 faced high liquidity constraints, and that firms' size and financial structure contributed to distinguish between firms that were more or less liquidity constrained. Latruffe (2005) confirmed the presence of rural credit market imperfections in Poland during 1996-2000, in the sense that, for some farms, the only source or the least expensive source of funds, were internal funds. O'Toole et al. (2014) suggested that the Irish farm sector encountered difficulties in accessing credit to invest in productivity enhancing technology. A third type of determinants of investment relates to public policy, namely public support, tax system, standards or regulations. Sckokai and Moro (2009) found, for a sample of Italian specialised arable crop farms during 1994-2002, that an increase in intervention price would significantly affect farm investment, mainly through reduced price volatility. A fourth type of determinants is structural, relating to the quasi-fixity of assets, irreversibility of investment, sunk costs 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 farmers and herd become more familiar with new machines and technologies. Bokusheva et al. (2009) showed that the adjustment-cost model is adequate for evaluating investment behaviour mainly in the farming sector 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 with age and education, and with personal attitudes or values.

The sixth determinant type is organisational and relates to 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 investments in the future, in line with the accelerator effect; on the other hand, farmers with a highly performing farm may postpone investments 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: not only performance influences investment decisions, but also conversely. In the literature, several authors have indeed shown that farm performance is influenced by investment (Sauer and Latacz-Lohmann, 2015; Zhengfei and Oude Lansink, 2006). Sauer and Latacz-Lohmann (2015) showed, for dairy farms in Germany for the period 1995-2010, that investment in innovative technology allows to increase

performance (measured by productivity of dairy production). Zhengfei and Oude Lansink (2006) showed, for Dutch cash crop farms over the period 1990-1999, that 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)), the explicit investigation of the effect of current performance on future investment decisions, accounting for endogeneity, has never been performed. Moreover, in the context of the end of milk quotas, structural changes could occur. The progressive ending of milk quotas initiated in 2008 could favor investment in some types of farms to the detriment of others. Is the link between performance and investment the same for capital intensive farms and less capital-intensive farms?

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 French dairy sector. 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 capital intensities. We indeed consider two types of farms that may have a different investment strategy: farms that have a high capital intensity, and farms that have a low capital intensity. Investment behaviour of both farm types may differ for several reasons. Farms may differ in their current performance, which would differently affect future investment decisions; the adjustment costs may also have a different impact depending on the initial capital endowment. Our model is applied to a sample of specialised Brittany dairy farms during the 2005-2014 period.

The article is structured as follows. Section two develops the theoretical framework. Section three describes the database while section four explains the econometric specifications. Section five presents the results and the last section concludes.

## **2 Theoretical framework**

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 optimizing 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 ensuring frictionless flow (maintenance), and may include gradual adjustments (refinements and improvements necessitating training) or more substantial adjustments (Caballero, 1999). In the profit's maximising framework, the adjustment cost hypothesis is formalized by including investment as an argument in the profit function. The adjustment cost model is particularly relevant for the agricultural sector. Asset fixity is a particular feature of this sector, especially in livestock sector, as Galbraith and Black (1938) argued early. Farms' fixed production factors are lumpy, implying that their reduction or reorganization is costly explaining why farms may be unprofitable in the short run.

The theoretical model assumes that dairy farmers are risk neutral and maximize the expected net present value of their profits  $\pi$  at time  $t$  over an infinite horizon (eq. 1):

$$\text{Max } E_t \left\{ \sum_{t=0}^{\infty} \beta_t \pi_t \{K_t, I_t, X_t\} \right\} \quad (1)$$

on  $K_t, I_t, X_t$

subject to

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

$$\pi_t \{K_t, I_t, X_t\} \geq 0 \quad (3)$$

where the capital  $K_t$  is a stock variable and the investment  $I_t$  is a flow variable;  $X_t$  is the level of variable inputs;  $\beta$  is the discount factor;  $\delta$  is the depreciation rate;  $E_t$  is the expectation operator conditional on information available at the start of period  $t$ , expectations being taken over future prices and technologies (Bond and Meghir, 1994). For simplification the farm subscript  $i$  is dropped from all variables.

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

The Lagrangian function can be written as follows:

$$L = E_t \left\{ \sum_{t=0}^{\infty} \beta_t \pi_t \{K_t, I_t, X_t\} \right\} + \dots + \lambda_t [I_t - K_t + (1 - \delta)K_{t-1}] + \lambda_{t+1} [I_{t+1} - K_{t+1} + (1 - \delta)K_t] + \dots + \mu_t [\pi_t \{K_t, I_t, X_t\}] + \mu_{t+1} [\pi_{t+1} \{K_{t+1}, I_{t+1}, X_{t+1}\}] \quad (4)$$

where  $\lambda_t$  and  $\mu_t$  are the Lagrangian multipliers associated with constraints (2) and (3) respectively.

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

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

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

Combining first order conditions (5) for investment and (6) for capital gives:

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

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  $\varepsilon_{t+1}$  is an error term that is assumed to be uncorrelated with 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 production function;  $C_t$  is the adjustment cost function;  $w_t$  is the variable input price and  $p_t^I$  is the investment price.

To model the link between performance and investment decisions, we assume that the output depends not only on the production factors (fixed and variable inputs), but also on a performance parameter noted  $u_t$  (eq. 10), which could be viewed as 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 increasing with performance. We further assume that performance depends on capital stock, capturing size effects (eq.11 and ). However, no specific assumption is made on the sign of the first derivative of the performance function  $g$  with respect to capital, that is to say on the sign of the scalar  $b$  in equation (12): the derivative may be negative, respectively positive, meaning that farmers on larger farms would have a lower, respectively higher, performance than farmers operating smaller farms. It is assumed that the effect of capital size on performance depends on the level of performance itself (eq. 12), that is to say that the effect is amplified at high levels of performance.

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

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

The first derivatives of the production function with respect to capital and to performance are as follows (eq. 13 and 14):

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

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

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  $\alpha_0, \alpha_1, \alpha_2, \alpha_3$ . Equation (14) represents the intuitive idea that the higher the farmer's performance, the higher the output produced.

As it 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 is increasing with investment (eq. 16) and derivative with respect to capital depends on investment squared (eq. 17):

$$C_t = h(K_t, I_t) \quad (15)$$

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

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

Using equations (9), (10) and (15), the Euler equation in equation (8) can then be rewritten as follows (eq. 18):

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

Furthermore, using equations (12), (13), (14), (16), (17), it can be written as (eq. 19):

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

Assuming that the price of investment ( $p_t^I$ ) is constant across farms and years, the final model is therefore (eq. 20):

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

with:

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

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

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

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

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

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

Equation (21) shows that  $\vartheta_1$  is positive, and hence a positive impact of  $I_t$  on  $I_{t+1}$  is expected (eq. 20). As  $\theta_1$  is assumed to be positive and  $\frac{(\beta_t + \mu_t)}{(1-\delta)(\beta_{t+1} + \mu_{t+1})}$  as well, the direction of the impact of  $I_t^2$  on  $I_{t+1}$  (that is to say the sign of  $\vartheta_2$ , eq. 22) can inform on the sign of  $\gamma_1$  that is to say on the shape of the adjustment cost function (eq. 17). The sign of  $\vartheta_3$  (equation 23), related to the effect of  $u_t p_t$  on  $I_{t+1}$ , can inform on the sign of  $\alpha_3$  that is to say the direction of the impact of performance  $u_t$  on the marginal productivity of  $K_t$  (eq. 13). The sign of  $\vartheta_4$  (equation 24), related to the effect of  $X_t p_t$  on  $I_{t+1}$ , can inform on the sign of  $\alpha_2$  namely the effect of  $X_t$  on the marginal productivity of  $K_t$ . The direction of the impact of  $K_t p_t$  on  $I_{t+1}$  ( $\vartheta_5$ , equation 25) can inform on the sign of  $\alpha_1$  namely on the effect of  $K_t$  on the marginal productivity of  $K_t$ .

### 3 Data and econometric specification

The data set includes accountancy information for a fully balanced sample of 661 specialized dairy farms of one sub-region of Brittany (namely Ille-et-Vilaine with main town Rennes), provided by a regional private accounting office<sup>1</sup>, 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<sup>2</sup>. The output price ( $p_t$ ) is the milk sale price<sup>3</sup> in period  $t$ , milk being the main output for this farm sample. The variable input ( $X_t$ ) is proxied by operational expenses<sup>4</sup>, 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.

<sup>1</sup> CER FRANCE Ille-et-Vilaine. This accounting office manages the accounts of the majority of farmers in Brittany.

<sup>2</sup> 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.

<sup>3</sup> It was deflated by the price index of agricultural products with base year 2010.

<sup>4</sup> It was 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.



As a proxy of the managerial performance ( $u_t$ ), we use the current value of Earnings Before Interest, Taxes, Depreciation, and Amortization (EBITDA)<sup>5</sup> in period  $t$  divided by the number of labour units in the same period. EBITDA is an indicator of the operating profitability of a farm as 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 farm output generated. Relating the EBITDA to labour controls for size. A high EBITDA per labour unit at the end of period  $t$  reveals that the farmer has been highly performing in this period, and thus is a good proxy for high  $u_t$ .

As shown in Table 1, during the period considered, on average farms in the sample operated 77 hectares (ha) of utilized agricultural area (UAA), used 2 full-time equivalent labour units, bred 52 dairy cows producing 7,155 litres 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 smaller in terms of capital used (Agrete, 2010). They have a higher milk yield but a lower EBITDA per litre of milk.

Figure 1 displays, for our sample, the evolution of the yearly average level of investment and of milk price over the period considered. Total investment increases up to 2009, and then drops until 2011 where it increases again, continuously until the end of the period considered. The investment peak in 2007 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 and, at the same time, input prices remained at a high level. Milk price has since then been at its lowest level in historic terms.

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<sup>5</sup> The EBITDA was 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**

	Sample used (Sample's average over 2005-2014)	Total farm population in the same sub- region as our sample (Population's average in 2010; Agricultural Census)
<b>Structural variables</b>		
Milk produced (Litres)	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 (Litres / cow)	7,155	7,036
<b>Financial variables</b>		
Capital (€ / 1,000 Litres)	713	953
Indebtedness (%)	49.5	49.9
EBITDA (€ / 1,000 Litres)	150	173
<b>Number of observations</b>	661	3,248

Source: The authors 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 2005 and 2014**



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

Based on the theoretical model of farmer's investment decisions defined by equation (20), our baseline empirical specification is as follows (eq. 27):

$$\frac{I_{i,t+1}}{K_{i,t}} = \vartheta_0 + \vartheta_1 \frac{I_{i,t}}{K_{i,t}} + \vartheta_2 \frac{I_{i,t}^2}{K_{i,t}} + \vartheta_3 \frac{u_{i,t}p_{i,t}}{K_{i,t}} + \vartheta_4 \frac{X_{i,t}p_{i,t}}{K_{i,t}} + \vartheta_5 p_{i,t} + \vartheta_6 \frac{p_{i,t}}{K_{i,t}} + \varepsilon_{i,t+1} \quad (27)$$

where subscript  $i$  refers to the  $i$ -th farm and subscript  $t$  refers to the  $t$ -th period;  $\vartheta_0, \vartheta_1, \vartheta_2, \vartheta_3, \vartheta_4, \vartheta_5$  and  $\vartheta_6$  are parameters to be estimated;  $\varepsilon_{i,t+1} = s_i + w_{i,t}$  is the disturbance containing farm-specific effects  $s_i$  and random noise  $w_{i,t}$ .

All variables are divided by the net capital ( $K_t$ ) to control for farm size effect. We employ the generalised method of moments (GMM) (Arellano and Bond, 1991; Arellano and Bover, 1995) to account for potential endogeneity arising firstly from the correlation between explanatory variables and the error term, that can be due to a simultaneity bias or to unobserved heterogeneity such as soil conditions. Secondly, this enables to account for potential endogeneity arising from the correlation between the performance variable and the investment variable. As instruments we use internal instruments, that is to say the endogenous variables  $\frac{I_{i,t}}{K_{i,t}}, \frac{I_{i,t}^2}{K_{i,t}}, \frac{u_{i,t}p_{i,t}}{K_{i,t}}, \frac{X_{i,t}p_{i,t}}{K_{i,t}}, p_{i,t}$  and  $\frac{p_{i,t}}{K_{i,t}}$ , lagged over two periods (Barran and Peeters, 1998; Bond and Meghir, 1994; Rizov, 2004). We estimate the model in first differences (Bokusheva et al., 2009; O'Toole et al., 2014) to eliminate the farm-specific effect  $s_i$  from the investment equation.

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

Variables	Mean	Std. Dev	Min	Max	Number of observations
$\frac{I_t}{K_t}$	-0.0074	0.15	-1.36	0.85	5,949
$\frac{I_t^2}{K_t}$	7,097	25,287	0.00	1,107,676	5,949
$\frac{u_t P_t}{K_t}$	62	43	-80	1,223	6,610
$\frac{X_t P_t}{K_t}$	140	86	11	796	6,610
$\frac{P_t}{K_t}$	1.72e-03	1.09e-03	1.93e-04	13.4e-03	6,610
<b>Variables in levels</b>					
Investment ( $I_t$ ) (€)	3,270	55,070	-333,685	1,467,339	5,949
Output price ( $P_t$ ) (€ / 1,000 Litres)	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. The level of investment over the period is € 3,270 per farm on average in our sample. The standard deviation is high pointing out 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%, while it is 42% for positive investment values. The percentage of zero and negative values increases significantly since 2011 (not shown in Table 2). Output price is on average 327 € per 1,000 Litres. Variable input cost is on average 103,309 € and the variable input ( $X_t$ ) to output ( $Y_t$ ) ratio is about 0.48, with a high standard deviation (0.10) revealing a 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 hides here also a large heterogeneity across farms shown by the high standard deviation.

The heterogeneity revealed by Table 2 in terms of capital and variable inputs notably, indicates heterogeneous technologies across the sample. Such technological heterogeneity may imply differing adjustment costs, and hence differing impact. For this reason equation (27) is estimated twice, once on the whole sample and once with interaction effects when each explanatory variable is interacted with a dummy variable taking the value 1 if the farm has a “*high capital intensity*” and 0 if it has a “*low capital intensity*”. The dummy variable to identify both groups of farms is created as follows. Using Hierarchical Ascendant Classification (HAC) with Ward’s method, a cluster analysis is performed in order to identify 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<sup>6</sup> per hectare, LU/ha); the cost of work outsourcing per LU; the cost of concentrates per dairy cow; and the capital stock per LU. In order to distinguish farms based on the difference in their average capital intensity as well as on the difference in evolution over time, we use two types of variables: static ones, namely the average value over the whole period for each characteristic listed above; and dynamic ones, namely the growth rate computed between 2005 to 2014. The growth rate of the cost of work outsourcing is not used because it is correlated with other variables.

The HAC performed here allows identifying two clusters of farms in our sample (tables 3 and 4). Table 3 reports, for these two clusters, the descriptive statistics of the variables used for the classification, while table 4 presents descriptive statistics of additional characteristics of the clusters. On average, 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 (9 vs. 4%), 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€) than farms in cluster 2 (239 farms). Likewise, farms in cluster 1 experienced a higher growth of dairy cows (0.35 vs. 0.22) and stocking rate (0.06 vs. 0.01) between 2005 and 2014. This suggests that farms in cluster 1 are more capital intensive than farms in cluster 2 on average. 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*”.

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<sup>6</sup> Livestock Units (LU) allow aggregating 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 intensity farms (422 farms)	Cluster 2 Low capital intensity farms (239 farms)	t-test (equality of means)
<i>Average over 2005-2014 (standard deviation)</i>			
Number of dairy cows	55 (18)	48 (18)	***
Share of fodder maize in forage area (%)	9 (13)	4 (8)	***
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)	***
<i>Rate of growth between 2005 and 2014 (standard deviation)</i>			
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)	

*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 10, 5, 1 percent level.*

*Source: The authors based on CER FRANCE Ile-et-Vilaine*

**Table 4: Descriptive statistics of additional characteristics of the clusters**

	Cluster 1 High capital intensity farms	Cluster 2 Low capital intensity farms	Cluster 1 High capital intensity farms	Cluster 2 Low capital intensity farms
	Average in 2005 (standard deviation)		Average in 2014 (standard deviation)	
<b>Technical variables</b>				
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 (Litres)	355,350 (137,390)	266,916 (127,128)	508,786 (197,646)	346,466 (167,383)
Milk yield (Litres / cow)	7,375 (989)	6,076 (1,156)	7,962 (1,110)	6,475 (1,230)
<b>Financial variables</b>				
EBITDA (€)	87,022 (44,120)	65,922 (41,644)	90,770 (47,573)	65,112 (43,527)
EBITDA (€ / 1,000 Litres)	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 (%)	51.6 (20)	46.7 (22)	50.8 (20)	42.8 (21)
<i>Number of observations</i>	422	239	422	239

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). The results for the full sample are presented in the middle column. Results indicate that the model is highly significant, as shown by the Wald test. Also, the Sargan test of overidentifying 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  $t$  ( $\vartheta_1$ ), respectively the coefficient for the square investment to capital at period  $t$  ( $\vartheta_2$ ), are significant and positive, respectively, negative. This indicates that higher investments in period  $t$  increase investments in  $t+1$ , consistent with the model and suggesting that farmers smooth their investment over time in order to undergo the lowest adjustment costs. The latter are captured by the negative  $\vartheta_2$ , and hence the negative  $\gamma_1$  (see equation 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 the adequate framework for our sample.

Secondly, the coefficient for the variable including the performance indicator,  $\frac{u_{i,t}p_{i,t}}{K_{i,t}}$ , ( $\vartheta_3$ ) is non-significant (Table 5). This suggests that, for a given (positive) price, there is no effect of performance in  $t$  on investment in  $t+1$  when the full sample is considered. We will 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 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 year. The result is presented in the first row of Table 6. For the whole sample, the average price effect is 0.46 suggesting that when milk price increases (respectively decreases) by one Euro per 1,000 Litres, the ratio of investment to capital in period  $t+1$  increases (respectively decreases) by 0.46. This positive effect is conform to intuition 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, the estimation on the full sample does not show a significant effect of performance on investment, and this may hide heterogeneous behaviours within the sample as already revealed by the sample's descriptive statics. For this reasons we had separated 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 decisions, we estimate our investment model (equation 27) as an interaction model. More precisely, we interacted all explanatory variables with a dummy variable taking the value 1 for farms with high capital intensity and 0 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 group is low capital intensity farms. The coefficients for this reference group are those for the variables without interaction (i.e. when the dummy equals 0), while a coefficient for the high capital intensity farms is obtained by adding the coefficient for the variable without interaction and the coefficient with interaction. For example, the coefficient for the investment to capital ratio in period  $t$  is 0.717 ( $\vartheta_1$ ) 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 in period  $t$  is (significant and) positive for low capital intensive farms but (significant and) negative for high capital intensive farms, while the coefficient for the square investment to capital in period  $t$  is (significant and) negative for both sub-samples. While the latter result reveals that both sub-samples undergo adjustment costs, the result regarding the investment to capital confirms these 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  $\frac{u_{i,t}p_{i,t}}{K_{i,t}}$  ( $\vartheta_3$ ) is (significant and) negative for the high capital intensity sub-sample and (significant and) positive for the low capital intensity sub-sample. 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 these high capital intensive farms, when having invested in current period, decrease their investment in the next period so as to maintain their performance level.

On the opposite, during the period studied, a high performance in  $t$  has encouraged the low capital intensive sub-sample to invest in  $t+1$  (positive coefficient  $\vartheta_1$ ) in order to increase their size and hence their performance. This may be explained by the quotas removal which has progressively been implemented. Between 2008 and 2015, the dairy quota allocation has increased progressively to achieve a “soft landing”, creating new opportunities for Brittany dairy sector to take advantage of increasing global demand for dairy products even before the effective removal of quotas.

Thirdly, on average the effect of price in period  $t$  on investment to capital in period  $t+1$  is much lower for low capital intensive farms (0.03) than for high capital intensive farms (0.84) (Table 6). This discrepancy might suggest that low capital intensity farms still have a long way to go to adapt to the quota system elimination, more than high capital intensity farms. Low capital intensity farms need to invest whatever the economic conditions so as to be ready when quotas are effectively removed, and they do so regardless of the price levels.



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

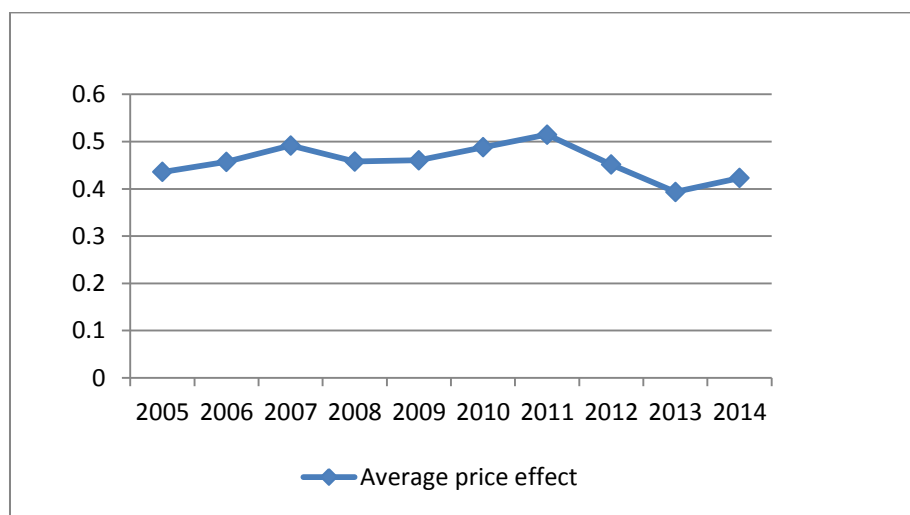
	Dependent variable: investment per capital in $t+1$	
	Whole sample	Whole sample (Interaction terms)
<i>(intercept)</i>	-0.103*** (0.0386)	-0.0836** (0.0359)
$\vartheta_1 \left( \frac{I_{i,t}}{K_{i,t}} \right)$	0.217*** (0.0437)	0.717*** (0.0656)
$\vartheta_1 \left( \frac{I_{i,t}}{K_{i,t}} \right) * \text{dummy high capital intensity farms}$		-0.944*** (0.0883)
$\vartheta_2 \left( \frac{I_{i,t}^2}{K_{i,t}} \right)$	-3.59e-06*** (6.43e-07)	-9.47e-06*** (1.21e-06)
$\vartheta_2 \left( \frac{I_{i,t}^2}{K_{i,t}} \right) * \text{dummy high capital intensity farms}$		4.98e-06*** (1.23e-06)
$\vartheta_3 \left( \frac{u_{i,t}P_{i,t}}{K_{i,t}} \right)$	0.0870 (0.283)	1.010** (0.446)
$\vartheta_3 \left( \frac{u_{i,t}P_{i,t}}{K_{i,t}} \right) * \text{dummy high capital intensity farms}$		-1.147** (0.483)
$\vartheta_4 \left( \frac{X_{i,t}P_{i,t}}{K_{i,t}} \right)$	1.160*** (0.207)	0.988*** (0.354)
$\vartheta_4 \left( \frac{X_{i,t}P_{i,t}}{K_{i,t}} \right) * \text{dummy high capital intensity farms}$		0.0189 (0.407)
$\vartheta_5(P_{i,t})$	-2.403*** (0.168)	-3.559*** (0.318)
$\vartheta_5(P_{i,t}) * \text{dummy high capital intensity farms}$		1.645*** (0.396)
$\vartheta_6 \left( \frac{P_{i,t}}{K_{i,t}} \right)$	447,759*** (35,416)	487,389*** (60,575)
$\vartheta_6 \left( \frac{P_{i,t}}{K_{i,t}} \right) * \text{dummy high capital intensity farms}$		-45,408 (72,201)
<b>Number of farm-year observations</b>	4,627	4,627
<b>Number of farms</b>	661	661
<b>Wald Chi2</b>	591.83***	787.06***
<b>Sargan test (p-value)</b>	0.0563	0.1716
<b>Instruments: lagged variables in period</b>	t-2	t-2

Notes: Robust standard errors in parentheses. \*, \*\*, \*\*\*: significance at 10, 5, 1 percent level.  
Source: The authors based on CER FRANCE Ille-et-Vilaine

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

	Number of observations	Mean	Standard deviation	Minimum	Maximum
Whole sample	6,610	0.46	1.61	-1.99	17.68
High capital intensity farms sub-sample	4,220	0.84	1.45	-1.52	15.05
Low capital intensity 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 price (in period  $t$ ) effect on investment per capital in  $t+1$  in the sample used 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 as well as ii) farmers' different investment strategies depending on the level of their farm capital intensity. For 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 during the 2005-2014 period, using an adjustment cost model and including farm performance in the modelling strategy. The model is also estimated with interaction terms that capture both sub-samples identified with HAC: high capital intensity farms and low capital intensity 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 for the full sample it is rather the high price perspectives that give incentives to farmers to invest than their performance. Thirdly, the influence of performance on farm investment differs between high capital intensive farms and

low capital intensive farms. Indeed, on average, the high capital intensity farms may prefer not to invest in order to avoid adjustment costs in the short term, while low capital intensive farms seem to invest all along the period regardless their performance and regardless milk prices. Their investment strategy might be linked to a strategy of increasing milk productivity in the perspective of dairy quota removal. Our findings highlight that farmers' heterogeneity needs to be accounted for in modelling investment behaviour. It allows reveal differentiated strategies and can help design targeted policies aimed at encouraging investment, in particular in the context of quota system elimination. Indeed, the structural changes are taking place in dairy sector, especially in the western part of France. An intensification of more extensive farm (grass-based systems) goes on to increase dairy productivity and, on the other hand, the investment of large structures is rather curbed by the existence of adjustment costs. So, it is possible to observe a standardization trend in terms of technology in this specialized dairy region which is on average more intensive than the others French region.

We should note here some limits to our analysis. Our objective was to investigate how performance was linked to farms' investment decisions, and in order to limit the complexity of the modelling framework and of the econometric estimations, we deliberately made some simplification assumptions. Firstly, we assumed that farmers' were risk neutral, although some literature has shown that some farmers may be 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, we have here proceeded in two steps, separating farms in a first step and investigating their investment decisions in a second step. But 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.

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