Farm investment and performance in the French (Brittany) dairy sector

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Abstract

This paper investigates the link between farm investment and farm performance considering two types of farms that may have a different investment strategy: farms that are intensive in capital, and farms that have a low capital intensity. Panel data on specialized dairy farms of one sub-region of French Brittany (Ille-et-Vilaine) for the period 2005-2014 were used. Results from adjustment cost models indicate that farms tend to smooth their investments to limit adjustment costs and that farm performance has a negative impact on investment.

Keywords: farms, investment, adjustment cost model, performance, France, Brittany, dairy sector, panel data.

JEL codes: D22, D24, D92, Q12

1. Introduction

Since the end of the 20th century and especially after 1950, the substitution of labour for capital has been one of the most striking features of the agricultural activity transformations. Technological change has been a major factor shaping agriculture in the last century (Schultz, 1964). A comparison of agricultural production patterns in France between the last century (1955) and the beginning of the 21th century (2000) shows that harvested cropland has declined, the share of the agricultural labour force in the total population has decreased substantially (from 31 to 4.8 percent), and the number of people now employed in agriculture has declined (from 6.2 million to 1.3 million); yet agricultural production in 2000 was higher than in 1955[1]. These statistics suggest that productivity has increased and agricultural production methods have changed significantly.

The restructuration of the agricultural sector in the mid of the 20th century has implied the enlargement of farms and substantial technological change. In the dairy sector there has been a growth in the livestock cattle per farm (in 1963 each farm had 7 dairy cows on average, while the figures were 17 in 1983, 33 in 2000 and 45 in 2010 (Agreste, 2011) and a more frequent use of selected breed and animals, so that, despite a high decrease of national dairy livestock (from 7.2 million dairy cows in 1983 to 4.4 million in 1997), the average annual deliveries per farm grew (66,000 litres per farm in 1983; 164,000 in 1997 and 320,000 in 2010), along with a higher resort to concentrate feed as well as equipment purchase such as stables and milking machines. This allowed an increase in animal productivity, labour productivity and land productivity. This restructuring was heavily influenced by the economic and political context. Indeed, since the 90's support to farmers includes the Second Pillar of the European Common Agricultural Policy (CAP), promoting farmers' investment through investment aids and settlement aids. Farms can also receive subsidies through the First Pillar of the CAP, namely coupled payments to specific crop hectares and livestock heads, and, later, decoupled payments. In the French dairy sector the share of subsidies in farm income

[1] Sources: French Ministry of Agriculture (agricultural censuses) and French statistical office INSEE (employment)

increased throughout the years: 17.2% in 1991, 36.5% in 1995, 55.9% in 2001 and 78.4 in 2005.

Another important contextual issue relates to the liberalization of trade. In the past recent decades, there have been several multilateral agreements with the objective of liberalizing trade. The CAP experienced several reforms, so as to better comply with global trade rules by lowering the guaranteed prices, export subsidies and Community preference. This has affected the dairy sector in the Western France area considered in this article: Brittany region, and particularly the Ille-et-Vilaine sub-region (whose main town is Rennes). In Brittany the dairy sector is one of the most important agricultural sectors, with 5.4 billion tons of milk produced in 2014 (21% of the regional agricultural output). The dairy sector also makes a significant contribution to sustaining Brittany's regional economy, with the dairy processing industry employing over 35,000 workers in 2013. In addition, the Ille-et-Vilaine dairy sector is the first French sub-region for the production of milk and beef calves. In 2010, the dairy farming sector in this sub-region included nearly half of the sub-region's professional farms, used half of the sub-regional utilised agricultural area (UAA) and employed 45% of the sub-regional agricultural labour. This 2003 CAP reform, called the Luxembourg reform, which replaced most of the coupled payments by decoupled ones (the Single Farm Payment – SFP), was implemented in a period of high international prices' volatility impacting farmers' decisions.

In this context, farmers need to adapt so as to remain competitive. Several strategies are possible: to decrease production costs through production optimization; to increase production level, that is to say to enlarge; to merge, specialize, or increase the added value by differentiation (e.g. via the introduction of labels or new practices) in order to maintain profitability. Most of these strategies require investments. Agricultural investment can take various forms such as land, building, planting equipment, and livestock. It can be investment for replacement as well as investment for growth or for modernisation. Investment for replacement is intended to replace worn out or obsolete goods, while investment for growth/modernisation implies the purchase of new capital or the adoption of new technology. The decreasing number of farms in France (-56% between 1988 and 2013) resulted in the decrease of the number of machines used in the agricultural sector, but farm size increase and greater specialization led to the use of more specific and powerful machines. Investment for growth/modernisation increased the productivity of labour, although this was possible up to some limits. This is why investment is now focused on the replacement of existing equipment, and on innovations aimed at increasing safety and improving farmers' working conditions (soundproof booths, air conditioning, GPS…) as well as improving the balance between farmers' private and professional life. It should also be kept in mind that farmers' investment strategies are influenced by the existence or not of shared machinery and the possibility to outsource work. In France, farmers can share machineries and pay only for their share, through farmers' cooperatives ('Coopératives d'Utilisation de Matériel Agricole', CUMA, in French), which are growing in importance (Agreste, 2016). Another increasing trend is to outsource work to private companies, most of them being run by farmers themselves ('Entreprises de Travaux Agricoles', ETA, in French), which avoids buying the machinery and may reduce costs (Dupraz and Latruffe, 2015).

Investment in technology, especially in machinery, is supposed to improve farm productivity but is however a significant financial burden on farms. In French farms, the mechanization costs represented on average 19% of total farm expenses in 2014 (Agreste, 2016). Hence, the effect of investment on farm performance may be ambiguous. To assess the profitability of the purchased equipment (on the medium or long term), several factors have to be taken into account such as the purchase price, the maintenance and fuel costs, the labour productivity increase and time savings, the potential tax deductions, the future resale price, as well as the specificities of the farming sector such as sunk costs. The latter imply that investment decisions are mostly irreversible due to the fact that capital is nonconvertible (the so-called asset fixity in agriculture) (Chavas, 1994). Sunk costs also arise due to learning cost, and the fact that this sector is highly supported by public subsidies, as explained above.

Farms' investment behaviour is affected by systemic changes in the farm environment, forcing farms to introduce some adjustments in their organization, management and other internal characteristics, adjustments that could be different according to the farm structure, especially its capital intensity. The literature on farm investment is substantial. Most of the recent studies used an adjustment cost model, where adjustment costs are considered (Bokusheva et al., 2009 ; Gardebroek and Oude Lansink, 2004; Hüttel et al., 2010). Contrary to studies on the industrial sector (Lizal and Svejnar, 2002; Rizov, 2004), no empirical result obtained for the farming sector is consistent with a priori theoretical expectations (Zinych et al., 2007). Consequently, much effort has been dedicated to develop efficient ways to estimate such models and to address important shortcomings that limit their applicability. One shortcoming is that all farms are supposed to use the same production technology and to have the same adjustment cost structure. As it may not be true in reality, some authors have relaxed this assumption by employing a fixed effects' specification, thus accounting for farms' heterogeneity (Whited, 1998). Another shortcoming is that dynamic models need to be adapted for negative and zero investments. Oude Lansink and Stefanou (1997) estimated separate models for negative and positive investment using only observations with non-zero observations. Pietola and Myers (2000) used full information maximum likelihood and a dynamic (dual) approach to model capital investment based on static price expectations. Later studies focused on the search of an empirically tractable model with the optimal regimes for positive, zero and negative investments (Gardebroek and Oude Lansink, 2004) and on the determinants of reluctant investment behaviour using a maximum entropy estimation (Gardebroek and Oude Lansink, 2004), a sequential conditional iterated Seemingly Unrelated Regression (SUR) in two stages (Serra et al., 2004), or a generalized Tobit model (Hüttel et al., 2010).

In this paper we will also use the adjustment cost model as it is theoretically appealing. 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 since the early 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). It is hypothesized that firms suffer a short-run output loss when they change their stocks of quasi-fixed factors. Adjustment costs include costs for frictionless flow (maintenance), gradual adjustment (refinements and improvements necessitating training) and major adjustments (Caballero, 1999). This short-run output loss might influence investment decisions and therefore the adjustment cost hypothesis is formalized by including investment as an argument in the profit function. The farmers' objective is to maximize the expected net present value of their profit over an infinite horizon, taking into account that, after investment, next period's profit may be reduced by adjustment costs. Marginal adjustment costs are assumed to increase with the size of investment, implying that it is always cheaper for the farmer to spread investments over time rather than to adjust instantaneously. Therefore, convex adjustment costs provide an explanation for sluggish adjustment of quasi-fixed factors. In an adjustment cost modelling framework it is assumed that firms exhibit profit-maximizing behaviour, that product and factor prices are constant across periods and firms, and that the firms' discount factor is constant over time.

As mentioned above, asset fixity is a particular feature of the agricultural sector. As early as the 30's, Galbraith and Black (1938) argued that high fixed costs contribute to the lumpiness of important production factors, which makes their temporary reduction or reorganization so expensive that farms are unprofitable in the short run. Later, Johnson and Pasour (1982) hypothesized that productive assets are trapped in agriculture because of a divergence between acquisition costs and salvage value: this is the sunk cost problem. Compared to agents in other economic sectors, farmers have a greater tendency to continue an activity once an investment in money, effort or time has been made. This is even more the case when considering farms' specialization process. For example, one in two farms in Ille-et-Vilaine is specialized in dairy production. Given the structure of the agricultural sector, it can be expected that adjustment costs due to asset fixity might be not negligible. In fact, the purchases of machinery and equipment can be substantial (31,600 € per farm and per year on average in the French dairy sector in 2014) and mechanization costs also constitute a large share of operating expenses (21% in the French dairy sector, 26% in the French beef sector in 2014) (Agreste, 2016). Likewise, the resale of used equipment also increased over time, probably because of some economic and fiscal strategies. In 1980, 22% French farmers sold their equipment and tool while in 2014, the respective figure was 38%. The overall ratio between disposals and acquisitions, was 15% in 1980 and 30% in 2014, reflecting a faster equipment and machinery renewal. Irreversibility is also crucial in agriculture: it may be caused by a wedge between acquisition and salvage values for farm specific assets, or because the adjustment costs for disinvestment are not the same as for investment (Arrow, 1968; Caballero, 1991; Dixit and Pindyck, 1994). If investments can be delayed, irreversibility makes them especially sensitive to uncertainty (Pindyck, 1990).

In this context, the objective of this paper is to provide a new view on investment decisions in the dairy sector. Firstly, we will account for the link between farm investment and farm performance in our modelling strategies. More specifically, we will account for the fact that performance may influence investment decisions. In the literature, several articles have shown that performance is influenced by investment (e.g. (Dong et al., 2016; Sauer and Latacz-Lohmann, 2015; Zhengfei and Oude Lansink, 2006). However, although the endogeneity of both variables is sometimes recognised and controlled for (e.g. Zhengfei and Oude Lansink, 2006), the explicit investigation of the effect of (current) performance on (future) investment decisions has never been performed. On the one hand, a strong farm performance can allow farmers to afford investments; on the other hand, farmers with a highly performing farm may postpone investments in order to avoid adjustment costs that would decrease performance. Secondly, we will consider two types of farms that may have a different investment strategy: farms that are intensive in capital, and farms that have a low capital intensity (Chandler, 1962; Lööf and Heshmati, 2002; Patnaik, 1972). Investment behaviour of both types of farms may differ for several reasons. Both types of farms may differ in their objective (capital accumulation vs. maintenance of profitability); they may differ in their current performance, which would affect differently future investment decisions; the adjustment costs may have a different impact depending on the initial capital endowment.

The remainder of this paper 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

The theoretical framework model used here assumes that farmers maximize the expected net present value of their profits π at time t, over an infinite horizon:

$$Max\ E_t\ \{\sum_{t=0}^{\infty} \beta\pi_t\{K_t, I_t\} + D_t - (1 + r_{t-1})D_{t-1}\} \quad (1)$$
$$\text{on } K_t\ , I_t\ \ , D_t$$

subject to

$$K_t = (1-\delta)K_{t-1} + I_t \quad (2)$$
$$\pi_t\{K_t, I_t\} + D_t\ - (1 + r_{t-1})D_{t-1} \geq 0 \quad (3)$$

where the capital K_t is a stock variable and the investment I_t is a flow variable; β is the discount factor; r_t is the interest rate; δ is the depreciation rate; D_t denotes debts; E_t is the expectation operator conditional on information available at the start of period t.

Equation (2) is the expression for capital accumulation, stating 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 reduced by debt payments is positive at each period.

The corresponding Lagrangian is:

$$\text{L}=E_t\{\sum_{t=0}^{\infty}\beta\pi_t\{K_t,I_t\}+D_t\text{-}(1+r_{t-1})D_{t-1}\}+\cdots\lambda_t[I_t - K_t + (1-\delta)K_{t-1}] + \lambda_{t+1}[I_{t+1} - K_{t+1} + (1-\delta)K_t] + \cdots + \mu_t[\pi_t\{K_t,I_t\} + D_t\text{-}(1+r_{t-1})D_{t-1}] + \mu_{t+1}[\pi_{t+1}\{K_{t+1},I_{t+1}\} + D_{t+1}\text{-}(1+r_t)D_t] \quad (4)$$

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, capital K_t, and debts D_t are respectively as follows:

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

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

$$\frac{\partial L}{\partial D_t} = (\beta + \mu_t) - (1 + r_t)(\beta + \mu_{t+1}) = 0 \quad (7)$$

Combining first order conditions (5) and (6) gives:

$$E_t\left\{\frac{\partial \pi_t}{\partial I_t}\right\} + E_t\left\{\frac{\partial \pi_t}{\partial K_t}\right\} - (1-\delta)E_t\left\{\frac{(\beta+\mu_{t+1})}{(\beta+\mu_t)}\frac{\partial \pi_{t+1}}{\partial I_{t+1}}\right\} = 0 \quad (8)$$

Plugging equation (7) in equation (8) defines the optimal path of investment under the form of the following Euler equation:

$$E_t\left\{\frac{\partial \pi_t}{\partial I_t}\right\} = (1-\delta)\frac{1}{(1+r_t)}E_t\left\{\frac{\partial \pi_{t+1}}{\partial I_{t+1}}\right\} - E_t\left\{\frac{\partial \pi_t}{\partial K_t}\right\} \quad (9)$$

This Euler equation equates the marginal costs of investing in current period *t* (left-hand side of the equation) and the marginal costs of postponing investment until the next period (right-hand side of the equation). It means that the farm is indifferent between investing today and transferring those resources to tomorrow.

The Euler equation defining the optimal investment path is generally estimated by assuming rational expectations (Muth, 1961). This implies that the expected value in period *t-1* is equal to the value in period *t* corrected with an error term. Thus, we introduce an expectational error in equation (10). $E_t\{\quad\}$ 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).

$$E_t\left\{\frac{\partial \pi_t}{\partial I_t}\right\} - \frac{(1-\delta)}{(1+r_t)}E_t\left\{\frac{\partial \pi_{t+1}}{\partial I_{t+1}}\right\} + E_t\left\{\frac{\partial \pi_t}{\partial K_t}\right\} = \varepsilon_{t+1} \quad (10)$$

where ε_{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:

$$\pi_t\{K_t, I_t, X_t\} = p_t Y_t - C_t - w_t X_t - p_t^I I_t \quad (11)$$

where p_t is the output price; Y_t is the output supply; X_t is the level of variable inputs; C_t is the adjustment cost; w_t is the variable input price and p_t^I is the investment price. This specification shows that the farm faces a loss in profit due to adjustment costs when installing the new capital. The production function is assumed to depend on the fixed and variable inputs and on a performance parameter:

$$Y_t = f_1(K_t, X_t, u_t) \quad (12)$$

where u_t is the farm performance.

Y_t is supposed to be quadratic and increasing with performance, with performance assumed to depend on capital stock.

$$u_t = f_2(K_t) \quad (13)$$

$$\frac{\partial u_t}{\partial K_t} = b u_t \quad (14)$$

It is a common assumption that output is influenced by a performance parameter which represents the managerial capacity of the farmer (Galanopoulos et al., 2006; Ondersteijn et al., 2003; Solano et al., 2006). Assuming that such performance depends on the capital stock is also realistic (equation (13)), as this is related to size effects. Here we make no assumption on the sign of the derivative of such performance with respect to the capital stock, that is to say with respect to size: it may be negative (positive) meaning that farmers on larger farms have a lower (higher) performance. However, as shown by equation (14), we assume in addition that the effect of size on performance depends on the level of performance, and more precisely that the effect is reinforced or reduced (depending on the sign of parameter *b*) at high levels of performance.

The first derivatives of Y_t can be written as follows:

$$\frac{\partial Y_t}{\partial K_t} = \alpha_0 + \alpha_1 K_t + \alpha_2 X_t + \alpha_3 u_t \quad > 0 \tag{15}$$

$$\frac{\partial Y_t}{\partial u_t} = a > 0 \tag{16}$$

The adjustment costs incurred by farms are assumed to be quadratic and to depend on K_t and I_t:

$$C_t = f_3(K_t, I_t) \tag{17}$$

$$\frac{\partial C_t}{\partial I_t} = \beta_0 + \beta_1 I_t \qquad \text{with } \beta_1 > 0 \tag{18}$$

$$\frac{\partial C_t}{\partial K_t} = \gamma_0 + \gamma_1 {I_t}^2 \tag{19}$$

The Euler equation in (10) can then be rewritten as follows:

$$\frac{\partial \pi_t}{\partial C_t}\frac{\partial C_t}{\partial I_t} - p_t^I - \frac{(1-\delta)}{(1+r_t)}\left(\frac{\partial \pi_{t+1}}{\partial C_{t+1}}\frac{\partial C_{t+1}}{\partial I_{t+1}} - p_{t+1}^I\right) + \frac{\partial \pi_t}{\partial Y_t}\frac{\partial Y_t}{\partial K_t} - \frac{\partial \pi_t}{\partial C_t}\frac{\partial C_t}{\partial K_t} = \varepsilon_{t+1} \tag{20}$$

that is to say

$$-(\beta_0 + \beta_1 I_t) - p_t^I - \frac{(1-\delta)}{(1+r_t)}(-(\beta_0 + \beta_1 I_{t+1}) - p_{t+1}^I) + p_t(\alpha_0 + \alpha_1 K_t + \alpha_2 X_t + \alpha_3 u_t) - \left(\gamma_0 + \gamma_1 {I_t}^2\right) = \varepsilon_{t+1} \tag{21}$$

Considering that the price of investment (p_t^I) and the interest rate (r_t) are constant across farms and years, the final model is therefore:

$$I_{t+1} = \vartheta_0 + \vartheta_1 I_t + \vartheta_2 {I_t}^2 + \vartheta_3 u_t p_t + \vartheta_4 X_t p_t + \vartheta_5 K_t p_t + \vartheta_6 p_t + \varepsilon_{t+1} \tag{22}$$

with:

$$\vartheta_1 = \frac{(1+r)}{(1-\delta)} \tag{23}$$

$$\vartheta_2 = \frac{\gamma_1}{\beta_1}\frac{(1+r)}{(1-\delta)} \tag{24}$$

$$\vartheta_3 = -\frac{\alpha_3}{\beta_1}\frac{(1+r)}{(1-\delta)} \tag{25}$$

$$\vartheta_4 = -\frac{\alpha_2}{\beta_1}\frac{(1+r)}{(1-\delta)} \tag{26}$$

$$\vartheta_5 = -\frac{\alpha_1}{\beta_1}\frac{(1+r)}{(1-\delta)} \quad (27)$$

$$\vartheta_6 = -\frac{\alpha_0}{\beta_1}\frac{(1+r)}{(1-\delta)} \quad (28)$$

Equation (23) shows that a positive impact of I_t on I_{t+1} is expected. As β_1 is assumed to be positive, and $\frac{(1+r)}{(1-\delta)}$ as well, the direction of the impact of ${I_t}^2$ (that is to say the sign of ϑ_2) will inform on the sign of γ_1 that is to say on the shape of the adjustment cost function (equation (19)). The sign of ϑ_3, related to the effect of $u_t p_t$ on I_{t+1}, will inform on the sign of α_3 that is to say the direction of the impact of performance u_t on the marginal productivity of K_t (equation (15)). The sign of ϑ_4, related to the effect of $X_t p_t$ on I_{t+1}, will inform on 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) will inform on the sign of α_1 namely of the effect of K_t on the marginal productivity of K_t.

3. Data

3.1 The sample

We use data on specialized dairy farms of one sub-region of Brittany (Ille-et-Vilaine) obtained from a regional private accounting agency[2] for the period 2005-2014 (ten years). This accounting agency manages the accounts of the major part of farmers in Brittany. For the present study, we use a fully balanced panel of 662 annual individual observations (farms) over the ten years period[3]. Hence, the pooled sample for the ten years includes 6,620 observations.

As shown in Table 1, during the period considered, farms in the sample operated 77 hectares (ha) of utilized agricultural area (UAA), used 2 full-time equivalent labour units and 52 dairy cows, and produced 7,120 litres of milk per cow, on average. In terms of representativeness of the sample, comparing to the exhaustive sample of specialized milk dairy farmers in Ille-et-Vilaine from the French 2010 Agricultural Census, farms in the sample were bigger that Agricultural Census' farms in terms of UAA and labour use, but had the same number of cows on average, and were smaller in terms of capital used (Agreste, 2010). They had a higher milk yield but obtained lower Earnings Before Interest, Taxes, Depreciation, and Amortization (EBITDA) per litre of milk and lower farm income per family labour unit.

The net capital stock (K_t) is the net value of fixed assets, including all tangible assets such as buildings, machinery[4] and tools, breeding livestock and land. Investment (I_t) is computed as

[2] CER FRANCE Ille-et-Vilaine

[3] The database provided by the accountancy office contains 28,672 observations. We removed observations that appear to suffer from data recording errors. We selected only farms having data over a complete accounting year (12 months). And we kept only farms which appeared each of the ten years to create a balanced sample. In total, around 77 per cent of the observations were dropped.

[4] It is worth noting that an investment in a milking machine is often accompanied by an investment in new or modernized buildings to adapt to the new technology. Thus, when an investment in a milking robot is made, half of it is allocated to the machinery investment category and the other half to the building investment category.

the difference, between periods t and t-1, of the net capital stock. 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. The output price (p_t) is the sale price of milk in period t, and was deflated by the price index of agricultural products with base year 2010. The variable input (X_t) is proxied by operational expenses, that are the costs related to the farming operations including in particular costs for animal feed, forage, livestock litter, fuel, veterinary products, animal reproduction, as well as costs for temporary labour and deflated by the price index of the means for agricultural production and more precisely the price index of consumer goods and services with base year 2010. The performance variable (u_t) is not directly observable in the database. The idea is that the farmer's performance in current period (u_t) influences his/her output in the current period (Y_t) and his/her investment decisions in the next period (I_{t+1}). Here we use the current (at t) value of EBITDA divided by the net capital stock as a proxy of the performance of the farmer. The ratio of EBITDA to capital, which will enter the econometric equation in place of u_t, is the ratio of return on capital used by bank analysts to measure the ability of capital to generate potential cash resources. It measures the potential cash flow obtained from the farm operation. It enables the farmer to maintain and develop the production facilities and to remunerate the capital used (equity and debt capital). It can thus be seen as a proxy for the farmer's managerial capacity, which influences the farm output generated. A high EBITDA to capital at the end of period t reveals that the farmer has been highly performing in this period, and thus can proxy a high u_t. Moreover, EBITDA is useful to compare farmers because its value is independent of fiscal optimization choices, although it is affected by changes due to capital intensity. The EBITDA was deflated by the price index of agricultural products with base year 2010.

Table 1**:** Descriptive statistics of the sample used and of the Ille-et-Vilaine farms population

	Sample used (Mean 2004-2014)	Ille-et-Vilaine (2010 Agricultural Census)
Technical variables		
Milk produced (Litres)	369,751	356,110
UAA (ha)	77	63
Number of dairy cows	52	52
Number of labour units	2.0	1.7
Milk yield (Litres / cow)	7,120	7,036
Financial variables		
Capital stock (€ / 1,000 Litres)	695	953
Indebtedness (%)	49.6	49.9
EBITDA (€ / 1,000 Litres)	136	173
Current farm income (€ / Family labour unit)	73	106
Number of observations	662	3,248

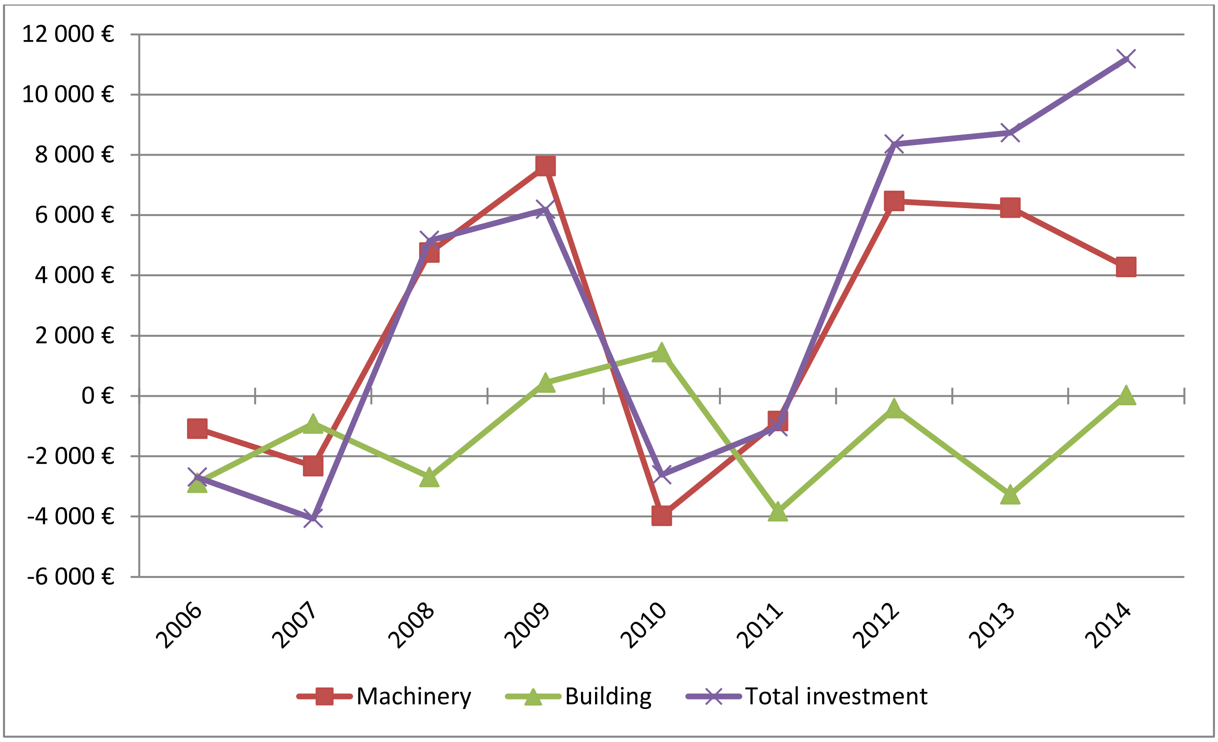
Source: The authors based on CER FRANCE Ille-et-Vilaine, and Agreste (2010)

Figure 1 describes the evolution of the yearly average level of the different types of investments in our sample between 2006 (where investment in 2006 is computed with the value of capital in 2006 and the value of capital in 2005) and 2014. 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 and this episode urged farmers to adapt their technology, maybe changing their perception of risk and their investment behaviour.

However, other reasons may influence investment behaviour. For instance, during the economic crisis (2008-2010) investment in buildings increased, contrary to investment in machinery and to total investment. Policy instruments such as the Plan of Modernization of Livestock Buildings, in 2007, co-funded by both the European Union and the Brittany region in the frame of the Second Pillar of the CAP, might have influenced farmers' investment behaviour. The purpose of this plan was to give incentives to farms to upgrade their production facilities and to improve their working conditions. Farm investment may have also been influenced by the cross-compliance scheme of the CAP within the 2013 reform, especially Statutory Management Requirements (SMRs) referring to 13 legislative standards in the field of animal welfare environment, food safety, animal and plant health.

The increase in farms' and livestock's size probably encourages farmers to enhance labour productivity, explaining the development of milking robot technology, especially among young farmers looking for more flexibility in their organization. Indeed, among the participants in the official performance control, in France the number of farms equipped with a milking robot has doubled since 2010 and has been multiplied by ten since 2005, but with a slight downturn in 2009 due to the dairy crisis; Ille-et-Vilaine being the most equipped region with milking robot (Idele, 2016). Other management choices in terms of labour organization consist in merging farms and herds or in increasing the number of hired workers. Investment behaviour also changes due to the development of farm machinery cooperative (CUMA) and of work outsourcing (ETA) as explained above, which avoids buying the machinery and may reduce costs.

Figure 1: Evolution of the average level of total net investment, building investment and machinery investment in the sample used from 2006 to 2014.



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 per farm and per year is € 3,243.19 on average in our sample. Most of it (72%) is made of machinery investment. As mentioned later, for the model estimation, all variables are related to capital stock (*K*). This enables controlling for size effects.

Table 2: Summary statistics of variables used in the estimation

Variables	Mean	Std. Dev	Min	Max	Number of observations
$\frac{I_t}{K_t}$	-0.0095	0.22	-11.44	0.85	5,958
$\frac{IM_t}{K_t}$	-0.0016	0.11	-1.37	0.60	5,958
$\frac{IB_t}{K_t}$	-0.0130	0.08	-0.34	0.69	5,958
$\frac{{I_t}^2}{K_t}$	7,195.71	26,390.49	0.00	1,107,676.00	5,958
$\frac{{IM_t}^2}{K_t}$	3,139.77	7,597.88	5,86E-06	235,212.50	5,958
$\frac{{IB_t}^2}{K_t}$	2,499.43	12,423.57	0.00	396,431.50	5,958
$\frac{u_t P_t}{K_t}$	10,894.17	5,866.04	-164,283.40	122,393.2	6,620
$\frac{X_t P_t}{K_t}$	14,100.15	8,974.79	1,157.76	219,101.20	6,620
$\frac{P_t}{K_t}$	0.17	0.15	0.02	8.80	6,620
Variables in levels					
Total investment (I_t) (€)	3,243.19	55,042.12	-333,685.30	1,467,339.00	5,958
Machinery investment (IM_t) (€)	2,347.30	32,485.54	-129,948.10	474,593.30	5,958
Building investment (IB_t) (€)	-1,341.53	33,194.94	-124,057.90	646,780.30	5,958
Output price (P_t) (€ / 1,000 Litres)	327.40	33.45	251.94	482.85	6,620
Variable inputs (X_t) (€)	103,213.50	84,189.79	5,352.94	1,102,166.00	6,620
Capital stock (K_t) (€)	256,418.70	152,242.60	4,543.74	1,943,785.00	6,620
Performance (u_t) (€)	77,830.96	46,109.86	-18,666.68	539,760.90	6,620

Notes: IM_t and IB_t are respectively machinery and building investment.

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

3.2 Classification of farms according to their capital intensity

Farms' investment behaviour is affected by systemic changes in farm environment, forcing farms to introduce some adjustments in their organization, management and other internal characteristics. We expect that these adjustments are different according to the farm structure, especially its capital intensity. For this reason, we investigate here the investment behaviour of two groups of farms that differ in terms of capital intensity.

For this, we use a Hierarchical Ascendant Classification (HAC) adopting Ward's method to 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 number of Livestock Units[5] per hectare (LU/ha) (i.e. stocking rate), the cost of work outsourcing per LU, the cost of concentrates per dairy cow, and the capital stock per LU. In order to distinguish the different farm structures (especially their capital intensity) as well as the different changes over time, we use two types of variables: static ones (i.e. the average values over the whole period) and dynamic ones, for which the rate growth is computed between 2005 to 2014, except for the cost of work outsourcing because it is collinear with other variables.

The HAC consists in searching for homogeneous groups of individuals (the clusters) in the population, that is to say groups which have a low within variability (i.e. the groups are homogenous) and a high between variability (i.e. the groups are different between each other). In other words, groups are chosen by ensuring a low intra-class inertia and high inter-class inertia. For that, the Duda-Hart index is computed (Milligan and Cooper, 1985). The number of groups is set when the smallest pseudo-t value is associated with the highest Duda-Hart index. Then, statistical tests (t-Student test for continuous variables) are used to identify whether the observation of a mean difference between the groups is significant or not.

The HAC performed here allows identifying two clusters of farms in our sample, whose description is shown in table 3 and table 4. Table 3 reports the variables used for the classification, while table 4 presents additional characteristics of the clusters. As shown by table 3, on average farms in cluster 1 (423 farms) exhibit significantly larger sizes (in terms of the number of dairy cows), are more intensive (with the highest share of fodder maize in forage area, stocking rate and concentrates cost per dairy cow) and have higher cost of work outsourcing per LU than farms in cluster 2 (239 farms). Likewise, farms in cluster 1 experienced a higher growth of dairy cows and stocking rate. Turning to characteristics that were not used to generate the clusters, table 4 confirms that farms in cluster 1 are on average larger (in terms of labour, land and output) and perform better in terms of milk yield. All this suggests that cluster 1 is a cluster that is more capital intensive than cluster 2. Thus, farms in cluster 1 will be called farms with high capital intensity, while farms in cluster 2 will be called farms with low capital intensity. When financial variables are compared across the clusters: although high capital intensive farms (cluster 1) have on average a higher EBITDA per farm than low capital intensive farms (cluster 2), the value of EBITDA for the former is lower when related to the milk produced and similar when related to the level of capital stock. Similarly, income is lower on average for high capital intensive farms and indebtedness level is higher, than for low capital intensive farms.

The two clusters, that differ in terms of capital intensity as well as performance, have in addition a different global investment behaviour, especially after the economic crisis. As shown by Appendices 1 and 2, the global investment of both clusters decreased between 2009 and 2010. However, while cluster 1 manages to increase its global investments during the rest of the period (2010-2014), cluster 2 increased its investments until 2011-2012 only. For this cluster, investments increased back in 2013-2014 after a slight decline in 2012-2013. After the economic crisis, although building investment follows the same trends in both clusters, the

5 Livestock Units are a way of 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 weight depending on its feed consumption.

amplitudes are greater in cluster 2. Concerning machinery, the investment increases between 2010 and 2012 and then falls until 2014 for cluster 1, while, in cluster 2, it increases continuously from 2010 to 2014.

Table 3: Variables used for the hierarchical ascendant classification analysis: averages (2005-2014) for the two clusters identified

	Cluster 1 (423 farms)	Cluster 2 (239 farms)	t-test (equality of means)
Mean of number of dairy cows	54.49 (18.23)	47.61 (18.22)	***
Mean of share of fodder maize in forage area (%)	0.09 (0.13)	0.04 (0.08)	***
Mean of stocking rate (LU / ha)	1.68 (0.28)	1.62 (0.28)	***
Mean of cost of work outsourcing per LU (€)	1.84 (0.73)	1.52 (0.79)	***
Mean of concentrates cost per dairy cow (€)	402.26 (88.03)	224.34 (55.13)	***
Mean of capital stock per LU (€)	79.08 (36.49)	66.78 (25.63)	
Rate of growth of number of dairy cows	0.35 (0.32)	0.22 (0.22)	***
Rate of growth of share of fodder maize in forage area	-0.10 (1.04)	-0.17 (0.78)	
Rate of growth of stocking rate	0.06 (0.21)	0.01 (0.15)	***
Rate of growth of concentrates cost per dairy cow	0.64 (0.55)	0.75 (1.17)	*
Rate of growth of capital stock per LU	0.21 (0.37)	0.22 (0.36)	

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

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

Table 4: Additional characteristics of the clusters: averages (in 2005 and in 2014)

Technical variables	Cluster 1 2005	Cluster 2 2005	Cluster 1 2014	Cluster 2 2014
Number of labour units	2.1	1.8	2.1	1.7
	(0.84)	(1.04)	(0.83)	(1.14)
UAA (ha)	76	61	89	68
	(33.88)	(31.20)	(43.10)	(34.25)
Milk produced (Litres)	354,908	266,916	507,848	346,466
	(137,528)	(127,128)	(198,351)	(167,383)
Milk yield (Litres / cow)	7,372	6,076	7,956	6,475
	(990.62)	(1,155.58)	(1,115.07)	(1,230.00)
Financial variables				
EBITDA (€)	86,953	65,922	90,511	65,112
	(44,083.84)	(41,643.93)	(47,813.21)	(43527.49)
EBITDA (€ / 1000 Litres)	169	195	123	146
	(103.22)	(109.66)	(57.44)	(69.18)
EBITDA / Capital stock	0.346	0.336	0.277	0.312
	(0.131)	(0.171)	(0.119)	(0.165)
Current income (€)	10,892	13,097	17,589	18,344
	(22,590.20)	(20,683.48)	(26,795.50)	(20,990.87)
Indebtedness (%)	51.6	46.7	50.8	42.8
	(21.86)	(22.35)	(20.12)	(21.38)
Number of observations	423	239	423	239

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

4. Econometric specification

Our baseline empirical specification is as follows:

$$\frac{I_{i,t+1}}{K_{i,t}} = \vartheta_0 + \vartheta_1 \frac{I_{i,t}}{K_{i,t}} + \vartheta_2 \frac{{I_{i,t}}^2}{K_{i,t}} + \vartheta_3 \frac{u_{i,t}p_{i,t}}{K_{i,t}} + \vartheta_4 \frac{X_{i,t}p_{i,t}}{K_{i,t}} + \vartheta_5 p_{i,t} + \vartheta_6 \frac{p_{i,t}}{K_{i,t}} + \varepsilon_{i,t+1} \qquad (29)$$

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 ϑ_6 are parameters to be estimated; $\varepsilon_{i,t+1}$ is the remaining disturbance, where the disturbance term $\varepsilon_{i,t+1} = d_t + s_i + w_{i,t}$ contains farm and year-specific effects (respectively s_i and d_t) and impermanent shocks $w_{i,t}$.

The equation is estimated several times: for total investment, for investment in machinery only and for investment in building only, and this for the whole sample, for the sub-sample of high capital intensive farms, and for the sub-sample of low intensive farms.

We use specific econometric considerations in estimating these nine investment equations. Firstly, our econometric methodology accounts for the potential endogeneity, that is to say the correlation between explanatory variables and the error terms, probably due to a simultaneity bias. To prevent this problem, we employ the generalised method of moments (GMM;

(Arellano and Bond, 1991; Arellano and Bover, 1995) with internal instruments. The instruments include the values of 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. In the literature, most obvious instruments are the lagged values of model variables (Barran and Peeters, 1998; Bond and Meghir, 1994; Rizov, 2004). Secondly, we eliminate the farm-specific effect s_i from this investment equation by estimating the model in first differences (Bokusheva et al., 2009 ; O'Toole et al., 2014).

5. Results

Table 5 provides the results of the estimation when total investment at period $t+1$ is taken as the dependent variable, for the full sample and for both sub-samples. Results show that the coefficient ϑ_1 for the investment to capital at period *t* is significant and positive, as expected. This suggests that higher investments in period *t* induce an increase in the investment level in $t+1$. This is consistent with the model specification. It shows that farmers smooth their investment over time in order to undergo the lowest adjustment costs. As the coefficient for the square of investment to capital (ϑ_2) is significant and negative, this indicates that the adjustment cost parameter $\gamma_1$is negative, suggesting that the marginal adjustment costs with respect to capital stock decreases for high levels of investment.

The coefficient for the performance ratio $\frac{u_{i,t}p_{i,t}}{K_{i,t}}$ (ϑ_3) is significant and negative. This means that, although performance increases the marginal productivity of capital (through a positive coefficient α_3), a high performance level in period *t* has a negative impact on investment at $t+1$ period, and this effect is even higher for high levels of prices. The negative effect of performance on investment in the next period suggests that farms performing in period *t* will prefer to avoid the loss in performance that may occur in the short term in period $t+1$ following investment and adjustment costs. Farmers thus refrain from investing, although this could increase their performance in future periods due to the link between u_t and K_t. Farmers thus have to make a choice between investing to be better performing in next periods, and not investing in order to avoid adjustment costs. Here farmers seem to prefer not investing to avoid adjustment costs.

The coefficient ϑ_5 is significant and negative. Although in the econometric specification this coefficient is attached to the price of output, in the theoretical model it is related to capital stock multiplied by the price of output. The negative sign would suggest that a high capital stock in period *t* discourages to invest in period $t+1$. Reversely having a low capital stock in period *t* may encourage to invest in period $t+1$. This suggests that farms with a high capital stock feel a lower need to increase their capital size, especially when knowing that investing may result in adjustment costs. The coefficient for the variable input ratio $\frac{X_{i,t}p_{i,t}}{K_{i,t}}$ (ϑ_4) is significant and positive. This means that farmers with a higher intensity of variable inputs with respect to capital tend to invest more. This may suggest that farmers relying highly on variable inputs invest so as to substitute variable assets with fixed assets because of the decreasing marginal productivity of inputs: indeed, one can note, from the signs of ϑ_4 and ϑ_5, that the marginal productivity of capital increases with capital (α_1) and decreases with variable inputs (α_2), suggesting that farmers have incentives to substitute variable inputs with capital.

Price in period t has a positive impact on investment in period $t+1$, which is conform to intuition: higher sale opportunities give incentives to farmers to expand, and thus to invest. This effect goes in opposition to the effect of performance: depending on whether the price is very high, one or the other effect might win on the other. The performance parameter includes the difference between output and input prices and the ratio on capital stock. It is much more linked to managerial performance and return on equity than the sole output prices. Thus, high prices do not always result in high performance and conversely.

Similar findings are obtained when only building investments are considered (see Appendix 3). When only machinery investments are considered, similar results to total investment are fund, except for ϑ_3, the coefficient for the performance ratio $\frac{u_{i,t}p_{i,t}}{K_{i,t}}$, which although still negative, is now non-significant (see Table 6). This discrepancy is to be explained by the different levels of capital intensity in the sample. While the two sub-samples of low capital intensity and high capital intensity behave similarly in terms of total investment (Table 5), their behaviour is slightly different in terms of machinery investment (Table 6). The only difference regards ϑ_3, the coefficient for the performance ratio which is significant and negative for the high capital intensity sub-sample and non-significant (and positive) for the low capital intensity sub-sample. Thus, high capital intensive farms are faced with the above-mentioned trade-off of investing now to increase their size and then their performance, and to postpone investment so as to not decrease their next year performance with adjustment costs. By contrast, low capital intensive farms' machinery investment behaviour is independent of their performance. This is confirmed by evolution graphs: Appendix 4 shows a decrease in performance (EBITDA) for both farm clusters after 2011. On Appendices 2 and 3, machinery investment become negative in 2010 and 2011 and remained rather variable since for high capital intensive farms while it remained regularly increasing since 2010 for low capital intensive farms. The fact that the latter farms continue to invest when EBITDA drops (Appendix 4) suggests a catch-up effect, that is to say low capital intensive farms increase their capital intensity.

Table 5: Results of the estimation with total investments per capital as the dependent variable

	Full sample	High capital intensity farms	Low capital intensity farms
$\boldsymbol{\vartheta_0}$*(intercept)*	-0.07 (0.04)	-0.06 (0.05)	-0.11* (0.06)
$\boldsymbol{\vartheta_1}\left(\frac{I_{i,t}}{K_{i,t}}\right)$	0.23*** (0.02)	0.24*** (0.02)	0.19*** (0.03)
$\boldsymbol{\vartheta_2}\left(\frac{{Ii_{,t}}^2}{K_{i,t}}\right)$	-3.64E-06*** (2.65E-07)	-3.72E-06*** (3.20E-07)	-2.97E-06*** (4.73E-07)
$\boldsymbol{\vartheta_3}\left(\frac{u_{i,t}P_{i,t}}{K_{i,t}}\right)$	-0.68*** (0.10)	-0.63*** (0.12)	-0.81*** (0.17)
$\boldsymbol{\vartheta_4}\left(\frac{X_{i,t}P_{i,t}}{K_{i,t}}\right)$	1.15E-05*** (1.24E-06)	1.05E-05*** (1.51E-06)	1.22E-05*** (2.19E-06)
$\boldsymbol{\vartheta_5}\left(P_{i,t}\right)$	-2.83E-05*** (1.42E-06)	-2.96E-05*** (1.87E-06)	-2.52E-05*** (2.07E-06)
$\boldsymbol{\vartheta_6}\left(\frac{P_{i,t}}{K_{i,t}}\right)$	5.36*** (0.15)	6.14*** (0.20)	4.42*** (0.24)
Observations	3,972	2,538	1,434

*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: Results of the estimation with machinery investment per capital as the dependent variable

	Total Full sample	High capital intensity farms	Low capital intensity farm
ϑ_0(*intercept*)	-0.09*** (0.02)	-0.10*** (0.03)	-0.06 (0.04)
$\vartheta_1\left(\frac{IM_{i,t}}{K_{i,t}}\right)$	0.21*** (0.02)	0.18*** (0.02)	0.32*** (0.04)
$\vartheta_2\left(\frac{{IM_{i,t}}^2}{K_{i,t}}\right)$	-7.2E-0.6*** (4.52E-0.7)	-6.05E-06*** (4.94E-07)	-1.3E-05*** (1.21E-06)
$\vartheta_3\left(\frac{u_{i,t}P_{i,t}}{K_{i,t}}\right)$	-0.10 (0.06)	-0.14* (0.07)	0.02 (0.12)
$\vartheta_4\left(\frac{X_{i,t}P_{i,t}}{K_{i,t}}\right)$	3.41E-06*** (8.11E-07)	2.98E-06*** (9.59E-07)	2.99E-06** (1.50E-06)
$\vartheta_5\left(P_{i,t}\right)$	-9.71E-06*** (9.30E-07)	-1.0E-05*** (1.20E-06)	-7.96E-06*** (1.42E-06)
$\vartheta_6\left(\frac{P_{i,t}}{K_{i,t}}\right)$	2.33*** (0.10)	2.80*** (0.13)	1.64*** (0.17)
Observations	3,972	2,538	1,434

*Notes: Robust standard errors in parentheses. *, **, ***: significance at 10, 5, 1 percent level.*
IM_t is machinery investment.

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

6. Conclusion

This article aimed at providing a new perspective on investment decisions in the farming dairy sector taking into account the link between farm investment and farm performance as well as the different strategies followed by farmers depending on the level of capital intensity of their farm. We used adjustment cost models in which performance was explicitly included for a sample of dairy farms in Western France (Brittany) in 2005-2014, separated into two clusters of high capital intensity farms and low capital intensity farms.

Firstly, results showed that, for both clusters of farms in the sample, smoothing their investment over time is found to be an optimal strategy in the presence of adjustment costs, as found by Gardebroek and Oude Lansink (2004). Secondly, farmers have to make a choice between investing in period *t* so as to increase their capital size and their performance in the long term, and not investing in order to undergo the least possible adjustment costs in the short term. Thirdly, the effect of performance on investment behaviour is different between the two sub-samples (high capital intensity vs. low capital intensity), when machinery investment is considered suggesting different investment behaviours.

Several avenues for further research can be mentioned. Firstly, as farmers make a choice between investing in period *t* and not investing, it can be interesting to consider present time preferences in our model by introducing life cycle of farms and farmers in order to better understand the trade-offs faced by farmers between short term and long term. Secondly, our result show that the managerial capacity of the farmer proxied by EBITDA is an important lever of investment. This can be widened to an investigation of labour management and labour productivity. Indeed, some management choices are made in terms of labour organization consisting in merging farms and herds or in increasing the number of hired workers. Investment behaviour also changes due to the development of farm machinery cooperatives (CUMA) and of work outsourcing (ETA) with skilled and efficient workers, which also avoids buying the machinery and may reduce costs. While it is not common, that the farmers use such services to perform specific tasks (management, accounting, etc.), it is likely that such practices are still developing in coming years and influence investment behaviours. Future research should therefore consider in investment models other ways of fulfilling capital and labour needs. Thirdly, it would be interesting to analyse the link between capital intensity and farm specialization in the dairy sector. Finally, capital intensity per farm has increased over recent years, partly due to the increasing complexity of production techniques. Even if current capital intensity increase tends to slow farms' future investment, this rise may encourage farmers to get into debt in order to stabilize the return on equity. Thus, farmers also face a trade-off between investing to maintain their competitiveness and getting indebted in order to maintain their sustainability. Hence, introducing debts into the investment model may help fine tune the conclusions.

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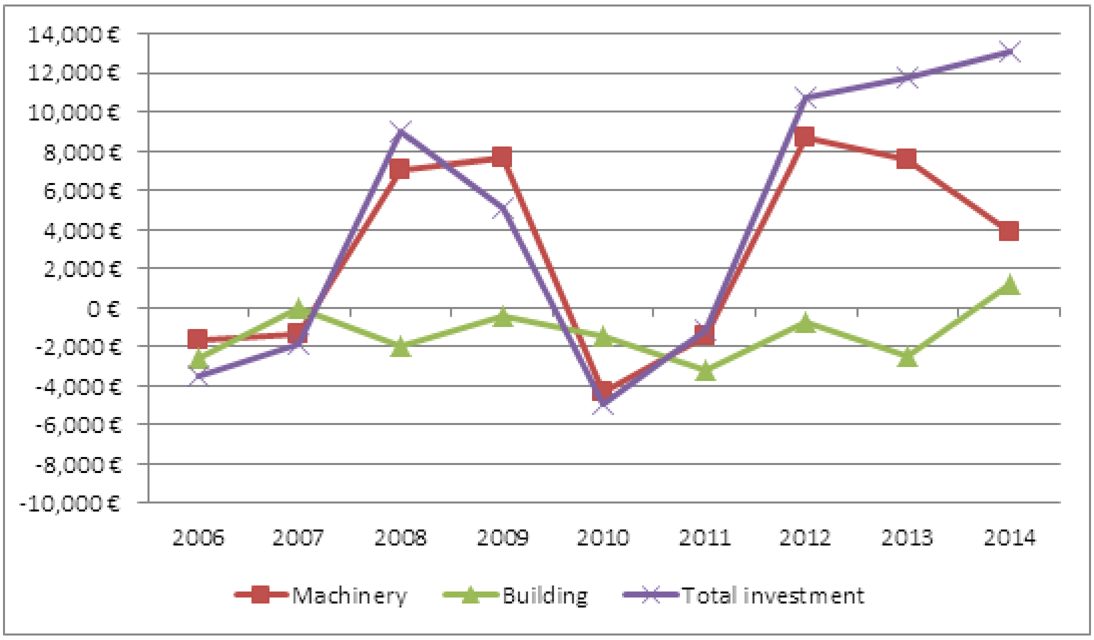
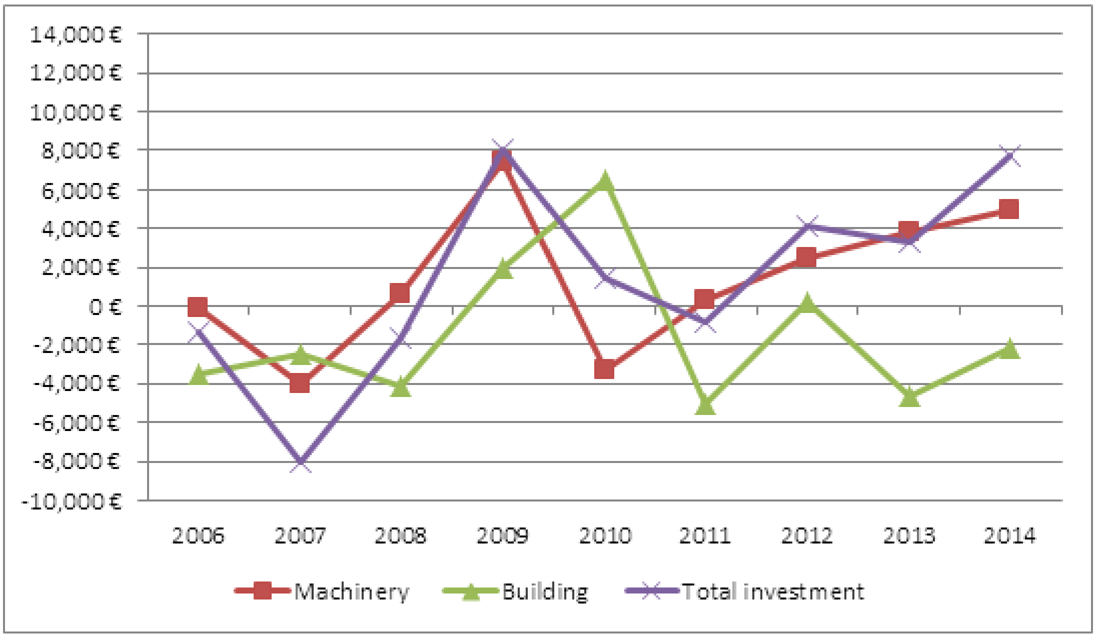
APPENDIX

Appendix 1: Evolution of the average level of total net investment, building investment and machinery investment from 2006 to 2014 for cluster 1 (high capital intensive farms)



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

Appendix 2: Evolution of the average level of total net investment, building investment and machinery investment from 2006 to 2014 for cluster 2 (low capital intensive farms)



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

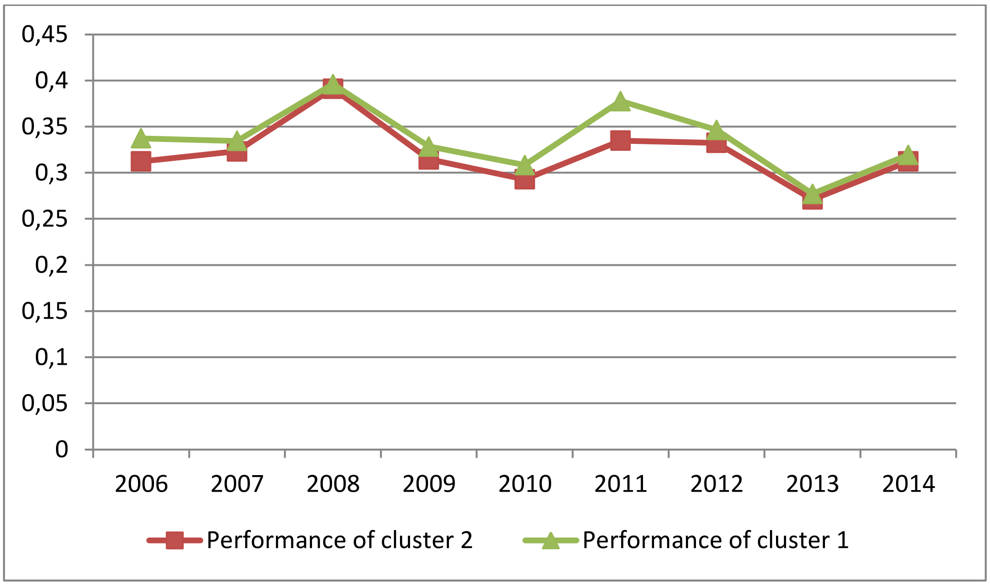
Appendix 3: Estimation results for building investments per capital as the dependent variable

	Full sample	High capital intensity farms	Low capital intensity farms
$\boldsymbol{\vartheta_0}$*(intercept)*	-0.03 (0.02)	-0.03 (0.02)	-0.06 (0.04)
$\boldsymbol{\vartheta_1}\left(\frac{IB_{i,t}}{K_{i,t}}\right)$	0.21*** (0.02)	0.22*** (0.03)	0.21*** (0.04)
$\boldsymbol{\vartheta_2}\left(\frac{{IB_{i,t}}^2}{K_{i,t}}\right)$	-3.89E-06*** (2.58E-07)	-4.6E-06*** (3.74E-07)	-3.14E-06*** (3.89E-07)
$\boldsymbol{\vartheta_3}\left(\frac{u_{i,t}P_{i,t}}{K_{i,t}}\right)$	-0.36*** (0.06)	-0.71*** (0.07)	-0.33*** (0.12)
$\boldsymbol{\vartheta_4}\left(\frac{X_{i,t}P_{i,t}}{K_{i,t}}\right)$	3.78E-06*** (7.43E-07)	3.42E-06*** (8.52E-07)	3.86E-06*** (1.51E-06)
$\boldsymbol{\vartheta_5}\left(P_{i,t}\right)$	-7.32E-06*** (8.34E-07)	-7.89E-06*** (1.04E-06)	-5.94E-06*** (1.40E-06)
$\boldsymbol{\vartheta_6}\left(\frac{P_{i,t}}{K_{i,t}}\right)$	1.47*** (0.09)	1.70*** (0.11)	1.19*** (0.16)
Observations	3,972	2,538	1,434

*Notes: Robust standard errors in parentheses. *, **, ***: significance at 10, 5, 1 percent level.*
IB_t is building investment.

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

Appendix 4: Evolution of the average performance u_t (EBITDA) from 2006 to 2014 for both clusters



Note: cluster 1 includes farms highly capital intensive, while cluster 2 includes farms low capital intensive.

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