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Ajustements des investissements agricoles aux changements de prix: Le cas des exploitations françaises en grandes cultures

Résumé

Dans cet article, nous étudions le comportement d'investissement d'agriculteurs français spécialisés en grandes cultures entre 2002 et 2014, en mettant l'accent sur leurs ajustements au prix de l'investissement et aux prix de la production agricole. Nous estimons un modèle économétrique de choix d'investissement agricole tenant compte de l'hétérogénéité des exploitations. Nous permettons aux paramètres de ce modèle de varier entre deux sous-périodes: 2002-2007 et 2008-2012, la seconde sous-période étant caractérisée par un niveau et surtout une volatilité du prix des récoltes nettement plus importants. Nos résultats montrent que pour des montants d'investissement importants, les comportements des agriculteurs ont changé après 2007 du fait d'un changement de leurs préférences vis-à-vis du risque. Ceci peut expliquer la relative stabilité de l'investissement agricole sur la période, malgré la forte augmentation des prix des récoltes et de leur volatilité à partir de 2007.

Mots-Clés : investissement, aversion au risque, prix, volatilité, grandes cultures, France

Classification JEL: Q12, D80

Responsiveness of farm investment to price changes: Evidence from the French crop sector

Abstract

In this article we investigate the investment behaviour of French crop farmers between 2002 and 2014, with a focus on their adjustments to investment prices and farm output prices, which became more volatile after 2007. We estimate an econometric model of farm investment accounting for farm heterogeneity and allowing for change in behavioural parameters after 2007. Our results show evidence of a significant behavioural change in large investments over time, related to a change in farmers' preferences toward risk, which can explain the relative stability of farm investment over the period, despite the strong increase in crop price levels and in crop price volatility after 2007.

Keywords: investment, risk aversion, prices, volatility, crop farms, France

JEL classification: Q12, D80

Responsiveness of farm investment to price changes:
Evidence from the French crop sector

1. Introduction

Farm investment in agriculture is crucial to improve farm competitiveness, sustainability and resilience. Investment allows farmers to adapt to changes in economic conditions *(e.g.* price variations, policy reform, climate change) and to adjust to public regulations (*e.g.* environmental or animal welfare regulations). Understanding how farmers make their investment decisions and how they adapt their investment behaviour in changing economic conditions, such as price changes, is therefore crucial. Farmers' investment decisions are influenced not only by investment prices (with lower investment prices encouraging investment), but also by output prices (with higher output prices encouraging investment in order to expand production). In his literature review on the modelling of firms' investment decisions, Chirinko (1993) concludes that firms' investment is more responsive to output quantities than to capital prices. His conclusion is notably based on Morrison (1986) who uses data on the U.S. manufacturing sector between 1947 and 1981 to estimate the elasticities of demand for capital with respect to the prices of capital and different variable inputs. Morrison's (1986) results show stronger responses of capital to output quantities than to input prices (including capital price). On that basis, one may expect investment to be essentially driven by output prices, and policies directly targeting investment costs to have only marginal impacts on investment decisions. In the agricultural economics literature dealing with farm investment, no consensus seems to emerge on the relative impacts of investment price and output price on farmers' investment decisions. For instance, Thijssen (1996), considering Dutch farms observed from 1970 to 1982, finds significant responses of investment to both investment and output prices and concludes that investment subsidies are good policy incentives to agricultural investment. On the other hand, the results obtained by Vasavada and Chambers (1986) in the case of U.S. agriculture show no response of quasi fixed factors to their own prices and a negative response to the price of output. Oude Lansink and Stefanou (1997) obtain the same puzzling effect of output price on investment in the case of Dutch cash crop farms between 1971 and 1992. More recently, Serra *et al.* (2009), using data for Kansas farms from 1997 and 2001, find investment to be more sensitive to output prices in periods of a favourable economic context (*i.e.* increase in capital stocks) and more sensitive to public subsidies in the case of poor economic conditions. These authors do not directly consider the responses of farmers to changes in investment prices, but their results demonstrate a sensitivity of farm investment behaviours to the economic environment. Sckokai and Moro (2009) also find the response of farm investment to depend on the economic context and notably on the volatility of agricultural markets. Their estimations have been conducted on data ranging from 1994 to 2003, a context of relatively stable agricultural prices, and thus low price uncertainty, compared to what has been observed since 2007. One important question is whether these changes in economic context have had an impact on farmers' investment behaviour.

Against this background, the objective of our article is to contribute to a better understanding of farmers' investment behaviour in a context of changing investment prices and output prices. We apply an econometric model of investment choices accounting for farm heterogeneity and farmers' risk aversion, to French crop farms specialised in cereals, oilseeds and protein seeds during the recent period 2002-2014. This period is characterised by relatively low and stable crop prices before 2007, and much higher and volatile crop prices since 2007, which makes it suitable for identifying the impact of a change in crop market conditions on farmers' investment decisions.

The remainder of the article is structured as follows. The next section describes the data and methodology we use to estimate the response of farm investment to price changes. The third section presents the results and the fourth section concludes.

2. Data and methodology

2.1. Data

To investigate the responsiveness of farm investment to price changes, we use a sample of farm-level data extracted from the French Farm Accountancy Data Network (FADN). Given data availability, the analysis covers the period 2002-2014. The FADN database, managed by the French Ministry of Agriculture, contains yearly data for a sample of French commercial farms that are representative of the French farm population in terms of production specialisations and regions. The French FADN database is a rotating panel with a rotation rate of about 10%, making the sample an unbalanced panel dataset. As investment types and levels may depend on production specialisations, we focus here on a specific type of farming, namely farms specialised in the production of cereals, oilseeds and protein seeds.

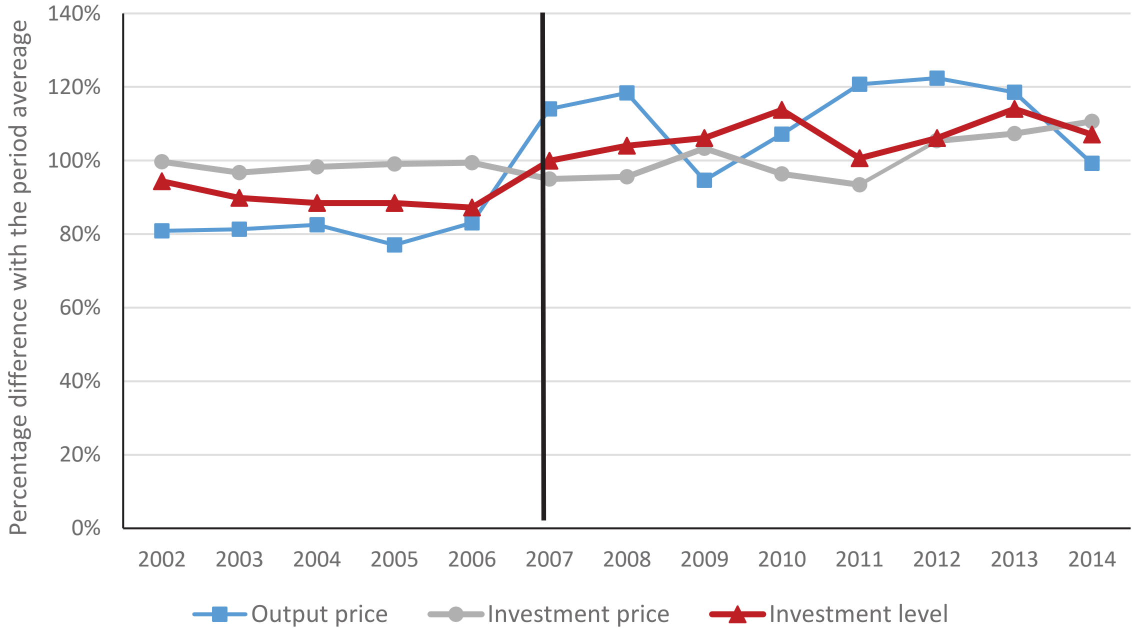
The investment level (I) we consider is net investment (we do not consider replacement investment) and is computed as an aggregate of machinery and building net investments. We exclude land investment as it is a minor part of farm investment.[1] In what follows, we consider that farms' owned utilised agricultural area (UAA) remains unchanged over the period, which is actually the case in our data where farms' UAA varies by less than 1% on average from one year to the other. As a result, land is also excluded from the fixed capital stock (k) that we consider in the remaining of the paper. As no price of investment (q) is available in the FADN database, we use as a proxy the ratio between annual debt repayments and the annual value of fixed capital stock. Given that cereal, oilseeds and protein seeds prices generally follow similar trends over time, we use the price of wheat, which is the most produced cereal in France, as a proxy of the price (p) of our specialized farm output (y). This price is calculated for each farm in each year using FADN data and is expressed in Euros per kilogram of wheat. As in Chavas and Holt (1996), the variance of output prices (σ), which represents the price risk faced by farmers, is defined as a weighted sum of squared deviations of past prices from their expected values. The capital depreciation rate (δ)[2] is assumed to be 0.05 and the official annual interest rate provided by the European Central Bank is taken as the actualisation rate (r). All values are measured at constant 2002 prices using the corresponding national price indices.

We focus on large investments to avoid heterogeneity issues in investment behaviour. As suggested by Kapelko *et al.* (2016), low levels of investment may be driven in large part by replacement motives and not profit maximization. In contrast, large investments are more likely to be motivated by profit maximisation. For this reason, we select the farms investing the most, *i.e.* the farms displaying investment levels higher than the sample average. The sample is unbalanced over the period, and we keep those farms that appear at least two consecutive years. After cleaning the data and eliminating outliers, the total number of observations in our sample during 2002-2014 is 3,822 (approximately 300 farms per year).

[1] While our sample data show investments in building and machinery in 80 out 100 cases, investments in land only occur in 10 out of 100 cases.

[2] Different values have been tested but estimation results are unchanged.

Figure 1: Evolutions of the sample's yearly averages of investment level, investment price and output price over the 2002-2014 period, in comparison with the period average



Source: The authors based on FADN data.

Note: the black vertical line indicates the separation between the two periods that differ in terms of price volatility.

Figure 1 reports the evolution of the yearly averages of investment level, investment price and output price over our sample period for the farms selected for our study. The annual values are not reported in levels, but as percentage differences compared to the average value for the full period. Three observations can be made. Firstly, investment levels and output price levels are lower up to 2006 than their levels increase from 2007 onwards. Secondly, while the investment price remains relatively stable during the whole period, the output price experiences ups and downs from 2007 onwards. This conforms to the general knowledge that worldwide crop prices (here wheat prices) are higher on average and much more volatile since 2007 (Von Braun and Tadesse, 2012). Thirdly, from 2007 onwards, farm investment does not follow the same evolution as output price. All these observations suggest that farmers' investment responses to prices may have changed during the whole period. For this reason, we will assess the impact of the change in market conditions on farmers' behaviour, by introducing a 'time period effect' in the key behavioural parameters of our econometric model.

Table 1: Descriptive statistics of the sample used

		Whole period		2002-2007		2008-2014	
		Mean	**S. D.**	**Mean**	**S. D.**	**Mean**	**S. D.**
Total utilised agricultural area (ha)		160	87	162	85	159	88
Capital (Euros/ha)	k	1,638	958	1,683	925	1,601	983
Output (Euros/ha)	y	1,057	588	950	388	1,142	698
Gross investment (Euros/ha)	I	415	301	399	269	427	324
Wheat price expectation (Euros/ton)	p	127	31	105	16	146	29
Wheat price variance	σ	447	403	55	53	760	266
Investment price	q	0.11	0.08	0.11	0.08	0.11	0.08
Depreciation rate	δ	0.05	-	0.05	-	0.05	-
Actualisation rate	r	0.022	0.015	0.028	0.008	0.016	0.017
		%		%		%	
Share of farms with individual legal status		50		53		49	
Share of farms in Parisian basin region		48		50		47	
Share of farms in South Western France region		15		15		15	
Share of farmers who have completed secondary education or above		71		67		74	
Share of farmers 50 years old or older		53		61		47	
Number of observations		3,822		1,700		2,122	

Source: The authors based on French FADN data.

Table 1 provides descriptive statistics of our variables of interest for the whole 2002-2014 period and for the two sub-periods. During the whole period the farms in our sample operated on average 160 hectares (ha) of UAA and used 1,638 Euros of capital per ha. The respective figures for the two sub-periods are very similar, indicating that, although it is not a balanced sample throughout the full period, structural characteristics are similar for the sub-sample of 2002-2007 and the sub-sample of 2008-2014.

On average during the whole period, farms produced an output of 1,057 Euros per ha per year and invested on average 415 Euros per ha each year (the minimum being 181 and the maximum 5,001 Euros). Table 1 clearly shows that farm investments are lower on average during the first sub-period. As observed on Figure 1, the investment price remains remarkably similar over the whole period (0.11 Euro paid for each Euro of capital, on average), while the output price is much higher in the second than in the first sub-period (146 *vs.* 105 Euros per ton of wheat). The increase in farm investments after 2007 thus seems, at first sight, attributable to an increase in output price levels leading to a higher crop production (1,142 *vs.* 950 Euros per ha) and thus higher needs in capital. The strong increase in output price volatility, observed on Figure 1 is also confirmed by the figures reported in Table 1. Given the potential negative impacts of market risk on farm investment decisions, this increase in price volatility may have mitigated the increase in investment induced by the output price increase. The econometric estimation of our investment model will allow further investigation of this issue.

About half of the sample farms have an individual (sole proprietorship) legal status, compared to partnerships or companies. About half of the sample farms are located in the wide Parisian basin area (administrative regions “Ile-de-France”, “Picardie”, “Champagne-Ardennes” and “Centre”), which is the main area for wheat production in France, while 15% of the farms are located in the other main wheat area, namely South Western France (administrative regions “Midi-Pyrénées”, “Aquitaine”, “Poitou-Charentes”). These two areas, Parisian basin area and South Western France, exhibit specific favourable characteristics for field crop farms, the former being a region with particularly good cropping conditions and large farms, and the latter being largely composed of farms specialized in irrigated corn production. Finally, in the second sub-period, farms are on average operated by younger farmers (with 61% of farmers being older than 50 in the first sub-period *vs.* 47% in the second sub-period), and who have a higher degree of education (with 67% of farmers having completed secondary education in the first sub-period *vs.* 74% in the second sub-period). This reflects the generation renewal trend in the French farming population.

2.2. Model and estimation strategy

Two types of approaches are generally used in the economic literature to investigate farmers’ investment decisions. Primal approaches rely on structural models obtained from the maximisation of future expected profit under technological constraints (*e.g.*, Gardebroek (2004) and Gardebroek and Oude Lansink (2004)), while in dual approaches, introduced by Epstein (1981), producers’ investment decisions are represented by value functions (*e.g.*, Oude Lansink and Stefanou (1997), Pietola and Myers (2000) and Sckokai and Moro (2009)). Models based on dual approaches allow for more flexibility in the representation of producers’ choices; however, their estimation necessitates sufficient variations in input prices across the sample, something that we do not have in our data.[3] For that reason, we follow here a primal approach. We consider the case where, at time t, the i-th farmer produces output y_{it} using variable inputs x_{it} and capital k_{it} under the production function $y_{it} = f(x_{it}, k_{it})$. We assume that this production function is strictly increasing and concave in (x_{it}, k_{it}). Capital evolves over time according to the following state equation

$$k_{i,t+1} = (1-\delta)\, k_{it} + I_{it} \tag{1}$$

where $\delta \in (0, 1)$ is the depreciation rate of capital and $I_{it} \in \mathbb{R}_+$ is investment at time t.

Market prices for (y_t, x_t, I_t) are respectively (p_t, w_t, q_t). In addition, when investing, the farm faces adjustment costs denoted by $\varphi(I_{it})$. The profit of the i-th farmer at time t is $\pi_{it} \equiv p_t\, f(x_{it}, k_{it}) - w_t x_{it} - q_t\, I_{it} - \varphi(I_{it})$. The farmer makes production decisions at the beginning of each period, with output $y_{it} = f(x_{it}, k_{it})$ obtained at the end of the period. Because of this production lag, the output price p_t is not known when inputs are chosen and is thus treated as a random variable. We denote the mean of the output price p_t by $\mu_{it} = E_{it}(p_t)$ and the variance of p_t by $\sigma_{it}^2 = E_{it}[(p_t - \mu_{it})^2]$, where E_{it} is the expectation operator based on the information available to the i-th farmer at the beginning of period t. The i-th farmer seeks to maximise the expected utility $E_{it}[U_i(\pi_{it})]$, where the utility function $U_i(\cdot)$ represents her/his risk preferences. Assuming that $U_i(\pi)$ is a strictly increasing function, we define the certainty equivalent as the sure amount CE_{it} satisfying $U_i(CE_{it}) = E_{it}[U_i(\pi_{it})]$ and the risk premium R_{it} as $R_{it} \equiv E_{it}(\pi_{it}) - CE_{it}$ (Pratt, 1964). In this context, R_{it} is the implicit cost of risk measuring the farmer's willingness to pay to eliminate risk by replacing the random variable π_{it} by its mean $E_{it}(\pi_{it})$. $R_{it} \begin{Bmatrix} = 0 \\ > 0 \end{Bmatrix}$ when $\frac{\partial^2 U_i}{\partial \pi^2} \begin{Bmatrix} = 0 \\ < 0 \end{Bmatrix}$, corresponding to the i-th farmer being $\begin{Bmatrix} \text{risk neutral} \\ \text{risk averse} \end{Bmatrix}$. Following Pratt (1964), we can approximate the risk premium as $R_{it} \cong \frac{1}{2}\, A_i\, y_{it}^2\, \sigma_t^2$, where A_i is the Arrow-Pratt coefficient of absolute risk aversion for the i-th farmer. Letting $A_i = B_i/(p_{it}\, y_{it})$, the risk premium can also be approximated as $R_{it} \cong \frac{1}{2}\, B_i\, \frac{y_{it}}{p_{it}} {\sigma_t}^2$, where B_i is a coefficient of relative risk aversion for the i-th farmer. Treating B_i as a constant corresponds to risk preferences exhibiting decreasing absolute risk aversion (as the absolute risk aversion coefficient A_i declines with an increase in expected revenue). In this context, for the i-th farmer at time t, the certainty equivalent CE_{it} is

[3] Contrary to cereal prices, which exhibit strong variations over our sample period, with coefficient of variation around 13 for output price indices using 2005=100 as a base year, the agricultural input price index remains almost stable over the same period, with a coefficient of variation around 0.7 using the same base year.

$$CE_{it} = E_{it}\big(p_t f(x_{it}, k_{it})\big) - w_t x_{it} - q_t\, I_{it} - \varphi(I_{it}) - \tfrac{1}{2}\, B_i\, \frac{y_{it}}{p_{it}} {\sigma_t}^2 \tag{2}$$

We assume that the i-th farmer maximises the expected present value of her/his certainty equivalents $\sum_{t=1}^{T_i} \left(\frac{1}{1+r}\right)^t CE_{it}$, where $r \geq 0$ is the interest rate, $1/(1+r)$ is the discount factor, and $T_i > 1$ is the farmer's planning horizon. Note that expectation about the future is still needed: future certainty equivalents are not perfectly known as the farmer learns about the distribution of future prices over time. Subject to the state equation (1), the i-th farmer's decisions at time t are represented by the following Bellman's equation

$$V_{it}(p_t, w_t, q_t, {\sigma_t}^2, k_{it}) = \max_{x_{i,t}, I_{i,t}} \Big\{ E_{it}\big(p_t f(x_{it}, k_{it})\big) - w_t x_{it} - q_t I_{it} - \varphi(I_{it}) - \\ - \tfrac{1}{2}\, B_i\, \frac{y_{it}}{p_{it}} {\sigma_t}^2 + \left(\frac{1}{1+r}\right) E_{i,t}\{V_{i,t+1}((1-\delta)\, k_{it} + I_{it})\} \Big\} \tag{3}$$

where $V_{it}(k_{it})$ is the value function defined recursively for $t = T_i, T_i - 1, \dots, 2, 1$, with $V_{i,T_i+1} = 0$.

Under differentiability and assuming interior solutions, the first-order necessary conditions for the optimal choice of (x_{it}, I_{it}) in (3) are

$$E_{it}\left(p_{it}\, \frac{\partial f_{it}}{\partial x_{it}}\right) = w_t + \tfrac{1}{2}\, B_i \frac{\partial f_{it}}{\partial x_{it}}\, \frac{{\sigma_t}^2}{p_{it}} \tag{4}$$

$$\left(\frac{1}{1+r}\right) E_{it}\left(\frac{\partial V_{i,t+1}}{\partial k_{i,t+1}}\right) = q_t + \frac{\partial \varphi_{it}}{\partial I_{it}} \tag{5}$$

with the simplifying notations $f_{it} = f(x_{it}, k_{it})$, $\varphi_{it} = \varphi(I_{it})$ and $V_{it} = V_{it}(k_{it})$.

Equation (4) gives the standard optimality condition for inputs, where marginal revenue is equal to marginal cost, the latter including both the input price w_t and the marginal cost of risk, $\frac{1}{2}\, B_i \frac{\partial f_{it}}{\partial x_{it}}\, \frac{{\sigma_t}^2}{p_{it}}$. As further discussed below, equation (5) has a similar interpretation for investment.

Applying the envelope theorem to equation (3) and combining with equation (5) yields

$$\left(\frac{1}{1+r}\right)\left(\sum_{s=t+1}^{T_i} \left(\frac{1-\delta}{1+r}\right)^{s-t} E_{it}\left[p_{is}\, \frac{\partial f_{is}}{\partial k_{is}} - \tfrac{1}{2}\, B_i \frac{\partial f_{is}}{\partial k_{is}}\, \frac{{\sigma_s}^2}{p_{is}}\right]\right) = q_t + \frac{\partial \varphi_{it}}{\partial I_{it}}\ . \tag{6}$$

The left-hand side in (6) is the present marginal value of capital, adjusted for the marginal cost of risk. And the right-hand side in (6) is the marginal cost of investment, including both the investment price q_t and the marginal adjustment cost $\frac{\partial \varphi_{it}}{\partial I_{it}}$. Thus, equation (6) states a familiar optimality condition: at the optimum, the present marginal value of capital equals the marginal cost of investment. Note that the marginal risk premium reduces the marginal present value of capital in (6). As such, under risk aversion (where $A_i > 0$, and hence $B_i > 0$), price risk, ${\sigma_t}^2$, and risk aversion, B_i, have negative effects on investment incentives.

Finally, we assume that farmer's expectations are naïve, that the production technology is Cobb-Douglas,[4] and that adjustment costs are quadratic as assumed by *e.g.* Weersink and Tauer (1989), Thijssen (1996), and Gardebroek and Oude Lansink (2004). Then, $E_{it}\left[p_{is}\,\frac{\partial f_{is}}{\partial k_{is}}\right] = p_{t-1}\frac{\partial f_{it-1}}{\partial k_{it-1}}$, $\frac{\partial f_{it}}{\partial k_{it}} = b\,\frac{y_{it}}{k_{it}}$ where $b \in (0,1)$ is the production elasticity of capital, $\varphi(I_{it}) = \theta + \beta\, I_{ti} + \frac{\alpha}{2}\, I_{it}^2$ where $\alpha > 0$, and the optimal investment decision rule is

$$I_{i,t} = -\frac{\beta}{\alpha} - \frac{1}{\alpha}\, q_t + \frac{b}{\alpha}\frac{(1-\delta)}{(1+r)^2}\left[1 - \left(\frac{1-\delta}{1+r}\right)^{T_i-t}\right]\left(\frac{y_{it-1}}{k_{it-1}}\right) p_{i,t-1} -$$
$$-\frac{1}{2}B_i\frac{b}{\alpha}\,\frac{(1-\delta)}{(1+r)^2}\left[1 - \left(\frac{1-\delta}{1+r}\right)^{T_i-t}\right]\frac{1}{p_{it-1}}\,\left(\frac{y_{it-1}}{k_{it-1}}\right)\,\sigma_t^2\ . \tag{7}$$

We can notice that, for any time $t \in [1, T_i]$, the term $\left(\frac{1-\delta}{1+r}\right)^{T_i-t}$ is positive but declines toward 0 as $T_i \to \infty$. It follows that a short planning horizon has a negative effect on the marginal present value of capital and thus on investment incentives. Notably, farmers close to retirement are less encouraged to invest.

Based on the model of farmers' investment in equation (7), we estimate the following econometric model:

$$I_{i,t} = a_{0,it} + a_{Q,it}q_{i,t} + a_{P,it}MVK_{i,t} + a_{V,it}MVR_{i,t} + \varepsilon_{i,t}\ , \tag{8}$$

where $MVK_{i,t}$ and $MVR_{i,t}$ respectively denote the marginal value of capital and risk expected by the farmer in period t in equation (11): $MVK_{i,t} = \frac{(1-\delta)}{(1+r)^2}\left(\frac{y_{i,t-1}}{k_{i,t-1}}\right)p_{i,t-1}$ and $MVR_{i,t} = \frac{1}{2}\frac{(1-\delta)}{(1+r)^2}\frac{1}{p_{it-1}}\left(\frac{y_{i,t-1}}{k_{i,t-1}}\right)\ \sigma_t^2$; $\varepsilon_{i,t}$ is the random error, and the a are parameters to be estimated.

The elasticity of investment with respect to the (observed) price of investment (eIq_{it}), the elasticity of investment with respect to the (expected) level of output price (eIp_{it}) and the elasticity of investment with respect to its volatility ($eI\sigma_{it}$) are, respectively,

[4] A translog production function was also tested in the empirical application but did not appear to fit the data since the estimated cross-term coefficients were not significant.

$$eIq_{it} = \frac{\partial I_{it}}{\partial PI_{it}} \frac{PI_{it}}{I_{it}} = -\frac{1}{\hat{\alpha}_{it}} \frac{q_{it}}{I_{it}}, \tag{9}$$

$$eIp_{it} = \frac{\partial I_{it}}{\partial p_{it-1}} \frac{p_{it-1}}{I_{it}} = \frac{\hat{b}_{it}}{\hat{\alpha}_{it}} \frac{\left(MVK_{i,t} + \hat{B}_{it} MVR_{i,t}\right)}{I_{it}}, \tag{10}$$

$$eI\sigma_{it} = \frac{\partial I_{it}}{\partial \sigma_t} \frac{\sigma_t}{I_{it}} = -\frac{\hat{B}_{it} MVR_{i,t}}{I_{it}}, \tag{11}$$

where

$$\hat{\alpha}_{it} = -\frac{1}{\widehat{a_Q}_{it}} \tag{12}$$

$$\hat{\beta}_{it} = \frac{\hat{a}_{0,it}}{\hat{a}_{Q,it}} \tag{13}$$

$$\hat{b}_{it} = -\frac{\hat{a}_{P,it}}{\hat{a}_{Q,it}} \tag{14}$$

$$\hat{B}_{it} = -\frac{\hat{a}_{V,it}}{\hat{a}_{P,it}} \tag{15}$$

$$\hat{A}_{it} = -\frac{1}{(p_{it}\, y_{it})} \frac{\hat{a}_{V,it}}{\hat{a}_{P,it}}. \tag{16}$$

$\hat{\alpha}_{it}$ and $\hat{\beta}_{it}$ are the estimated parameters of the capital adjustment cost function; $\hat{b}_{it}$ are the parameters of the production function; $\hat{B}_{it}$ and $\hat{A}_{it}$ are respectively the relative and absolute risk aversion coefficients. Their significance is computed through the delta method.

The potential impact of a short planning horizon on farmer's investment decisions (represented by term $\left(\frac{1-\delta}{1+r}\right)^{T_i - t}$ in equation (7)), is captured in the econometric model (8) by introducing a decomposition of parameters $a_{P,it}$ and $a_{V,it}$ according to the value taken by a dummy variable, $\mathbb{I}_{age,it}$. This variable takes the value of 1 for farmers aged 50 and more, *i.e.* for farmers close to retirement with a short planning horizon, and 0 otherwise.

As mentioned in data subsection, we also introduce a 'time period effect' in the key behavioural parameters of our econometric model (8) in order to assess the impact of the change in market conditions on farmers' behaviour. Two sub-periods are considered in our estimations: 2002-2007 and 2008-2014. Although changes in economic conditions start to be visible in 2007 (Figure 1), we make our second-sub-period start in 2008 as farmers have naïve expectations: their 2008 behaviour is thus based on conditions prevailing in 2007. A dummy variable, $\mathbb{I}_{2007,it}$, taking the value 1 for observations belonging to the second sub-period (2008-2014) of our sample and 0 for observations belonging to the first sub-period (2002-2007), is thus used to estimate the impact of the change in time period on the parameters of interest in our model representing the responses of farm investment to economic incentives. The parameter associated to the investment price in equation (8), $a_{Q,it}$, is thus decomposed as

$$a_{Q,it} = a_{Q,0}\left(1 + a_{Q,2007}\mathbb{I}_{2007,it}\right) , \tag{17}$$

where $a_{Q,0}$ represents the response to investment price in the first sub-period and $a_{Q,2007}$ the effect, on that response, of moving from the first to the second sub-period.

The dummy variable $\mathbb{I}_{2007,it}$ is also introduced in the parameters associated to the marginal value of capital $MVK_{i,t}$ and the marginal value of risk $MVR_{i,t}$ in order to estimate the impact of the change in time sub-period on the responses of farm investment to the level and volatility of output price. The parameters are thus decomposed in terms of age and sub-period as follows:

$$a_{P,it} = a_{P,0}\left(1 + a_{P,age}\mathbb{I}_{age,it}\right)\left(1 + a_{P,2007}\mathbb{I}_{2007,it}\right) \tag{18}$$

$$a_{V,it} = a_{V,0}\left(1 + a_{V,age}\mathbb{I}_{age,it}\right)\left(1 + a_{V,2007}\mathbb{I}_{2007,it}\right) . \tag{19}$$

To account for the potential heterogeneity in farm investment levels, the first additive term in equation (8), $a_{0,it}$, is decomposed as:

$$a_{0,it} = a_{0,0} + \mathrm{a}_{0,Z}{}'\mathrm{Z}_{i,t} + u_i , \tag{20}$$

where $\mathrm{Z}_{i,t}$ is a matrix composed of four dummy variable vectors representing farmers' characteristics and used to partly control for the heterogeneity in investment levels among farms. These variables include a variable capturing the education of farmers and taking the value 1 for farmers having completed secondary education and 0 otherwise; a variable showing the legal status of the farm and taking the value 1 for individual farms and 0 for partnership farms and companies; and two regional variables, the first one taking the value 1 for farms located in the large Parisian basin area and 0 otherwise, and the second one taking the value 1 for farms located in the South Western France and 0 otherwise. To control for the unobserved heterogeneity in investment levels, we also introduce an individual random effect u_i, assumed to be independent from the error of the model $\varepsilon_{i,t}$. Some unobserved factors that may have an impact on investment levels, like farmers' personal skills or extension access, may also influence farms' productivity. To deal with this potential correlation between the random term u_i and the exogenous variables in model (8), which would lead to biased estimates, we apply the Hausman-Taylor (1981) instrumental variable approach.

3. Results

Table 2 reports the regression results of the estimation of the investment model in equation (8), accounting for the decompositions of parameters presented in equations (17)-(20). We can first notice that the model fits the data relatively well, with a pseudo-R^2 of 0.63 and most parameters significantly estimated and of expected signs for the main variables of interest. The price of investment negatively affects farm investment per hectare (through parameter $a_{Q,0}$), similarly across both sub-periods (non significant parameter $a_{Q,2007}$). The value of the marginal capital productivity positively affects farm investment per hectare in both sub-periods, but more so in the first sub-period (through parameter $a_{P,0}$) than in the second sub-period (through $a_{P,0} + a_{P,2017}$). There is however no significant age effect, implying that the influence of productivity on investment is similar for younger and older farmers. As regard the marginal cost of risk, the effect on farm investment per hectare is negative, with a slight reinforcement in the second sub-period (parameter $a_{V,2017}$) and for farmers aged 50 or above (parameter $a_{V,age}$). Regarding the variables accounting for farmers' heterogeneity, farmers operating individual farms and having attained secondary education at least, invest more per hectare, while farmers operating farms in South Western France invest less per hectare than the other farmers.

Table 2: Estimated parameters of the investment model (8)

Variable	Estimated parameter	Standard error
Constant term ($a_{0,0}$)	357.41***	26.06
Dummy variables		
Individual legal status ($a_{0,Z1}$)	94.75***	15.00
Parisian basin area ($a_{0,Z2}$)	-8.55	14.39
South Western France ($a_{0,Z3}$)	-36.19*	19.78
Secondary education ($a_{0,Z4}$)	30.82**	14.94
Price of investment		
First period ($a_{Q,0}$)	-499.88***	105.73
Second period effect ($a_{Q,2007}$)	0.42	0.33
Value of marginal capital productivity		
First period ($a_{P,0}$)	0.77**	0.31
Second period effect ($a_{P,2007}$)	-0.45*	0.25
Age effect ($a_{P,age}$)	-0.48	0.30
Market risk (output price volatility)		
First period ($a_{V,0}$)	-112.74***	43.86
Second period effect ($a_{V,2007}$)	-1.06***	0.06
Age effect ($a_{V,age}$)	-1.08***	0.34
Wald Chi-square statistic	163.82***	
Pseudo-R^2	0.63	
Number of observations	3,822	

*Note: Significance levels: * 10%, ** 5%, *** 1%*

Source: The authors based on French FADN data.

The estimated model parameters reported in Table 2, as well as the variance-covariance matrix of estimates (not reported), enable us to calculate the value and the significance of the structural parameters that underlie the investment decision in equation (7), namely the parameters of the capital adjustment costs and production functions, as well as the relative and absolute risk aversion coefficients. Table 3 shows the values and significance of these structural parameters. As expected, the α parameter is positive implying that the capital adjustment cost function is convex. Similarly, the b parameter, which corresponds to the elasticity of production with respect to capital, takes values between 0 and 1, implying that the production function is concave. The relative and absolute risk aversion coefficients are positive in the first sub-period and not significantly different from zero in the second sub-period. What is noticeable is that the change in these risk aversion coefficients between both sub-periods is significant, while the changes in the adjustment cost function and production technology parameters between both sub-periods are not significant. It thus appears that farmers' investment behaviours have changed between both sub-periods and that this change can be attributed to a modification of their risk preferences: from relatively highly risk averse in the first sub-period with a risk premium ($R_{it} \cong \frac{1}{2}\ B_i\ \frac{y_{it}}{p_{it}}\sigma_t{}^2$) of about 170 Euros per hectare, which represents 18% of their production value, they become risk neutral in the second sub-period. It is also interesting to notice here that even if the increase in crop farm revenue between both sub-periods can partly explain the decrease in farmers' absolute risk aversion coefficient (A) under our DARA assumption, the fact that their relative risk coefficient (B) also significantly decreases suggests that this change in risk preferences is due to other (unobserved) factors. Such factors may relate to the change in socio-demographics characteristics of farmers across sub-periods. As the sample selected is unbalanced, some farms in the first sub-period are not observed in the second period, and reciprocally. Descriptive statistics show that farmers observed in the second sub-period are significantly younger and more educated (see Table 1). While this simply reflects the general trend on farms in France, it may contribute to the decrease in farmers' risk aversion across sub-periods.[5]

[5] We thank an anonymous Reviewer for pointing this out.

Table 3: Values and significance of the investment decision parameters

Parameters for		2002-2007	2008-2014	Significance of the difference between both sub-periods (prob>Chi2)
Capital adjustment cost function parameter	$\bar{\beta}$	-0.84*** (0.017)	-0.59*** (0.07)	0.18
Capital adjustment cost function parameter	$\bar{\alpha}$	0.002*** (0.0004)	0.001*** (0.0002)	0.17
Production technology parameter	$\bar{b}$	0.001*** (0.0004)	0.0007*** (0.0001)	0.31
Relative risk aversion coefficient	$\bar{B}$	72.08* (41.89)	-4.90 (8.99)	0.07*
Absolute risk aversion coefficient	$\bar{A}$	0.08* (0.05)	-0.004 (0.008)	0.07*

Notes: *Standard deviations of estimates are in parentheses. Significance levels: * 10%, ** 5%, *** 1%. The parameters $\bar{\beta}$, $\bar{\alpha}$, $\bar{b}$, $\bar{B}$ and $\bar{A}$ are the average values, over i and t of the estimated parameters.*

Source: *The authors based on French FADN data.*

The elasticities, computed along equations (9)-(11) with the parameters of Table 3 for each observation, are reported in Table 4 as averages for the sample. Both price levels elasticities, that is to say with respect to the price of investment and with respect to the price of output, are significant in both sub-periods considered and have the expected sign. Investment decreases with the price of investment and increases with the price of output. In absolute values, both elasticities are on average the same. This reveals that farmers are equally responsive to changes in the expected output price and in the investment price. There is no significant change in price elasticities on average across sub-periods. The elasticity with respect to price volatility is negative in the first sub-period, suggesting a negative impact of market risk on investment. It is positive, but not significant, in the second sub-period, and the change between both sub-periods is not significant as well. Given the significant change in farmers' risk preferences, it can, at first sight, seem counterintuitive that the elasticity of investment with respect to output price volatility, which depends on risk aversion, does not significantly vary between the two sub-periods. This result has in fact to be considered in regards to the strong increase in output price volatility from 2007: it is because farmers' preferences toward risk change, that the elasticity of investment with respect to output price volatility does not significantly vary over time.

Table 4: Average elasticities of investment computed for each observation and significance

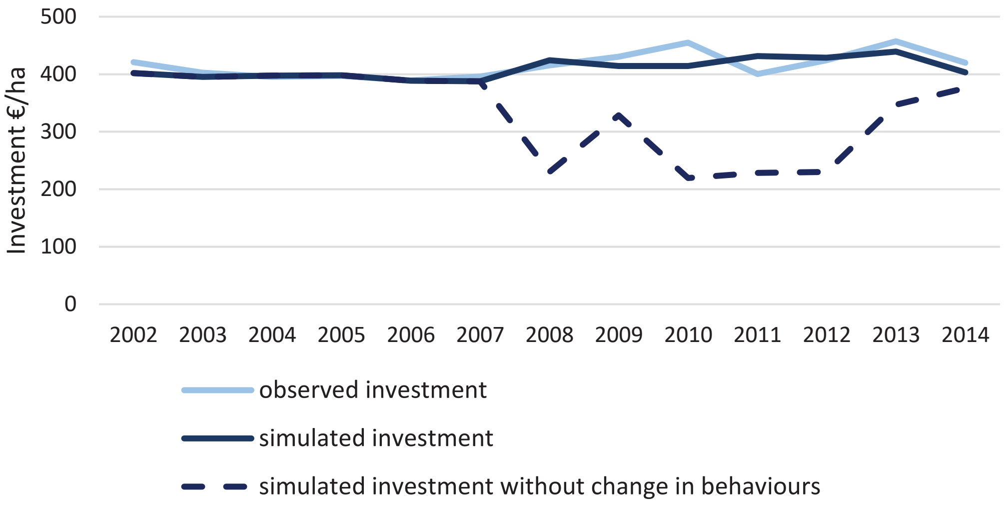
	2002-2007	2008-2014	Significance of the difference between both sub-periods (prob>Chi2)
With respect to investment price (eIq_{it})	-0.14*** (0.03)	-0.19*** (0.02)	0.12
With respect to output price level (eIp_{it})	0.14*** (0.06)	0.17*** (0.06)	0.64
With respect to output price volatility ($eI\sigma_{it}$)	-0.025* (0.018)	0.020 (0.034)	0.24

*Notes: Standard deviations of estimates are in parentheses. Significance levels: * 10%, ** 5%, *** 1%.*

Source: The authors based on French FADN data.

In order to further investigate the implications of the change in farmers' investment behaviour between the two sub-periods, we use the estimated investment model to simulate the evolution of farm investments between 2002 and 2014. Figure 2 reports the investment levels actually observed over the full period (light line) and the investment levels simulated with two versions of our model, based on observed market conditions (investment price, output price, output price volatility) and farmers' characteristics (age, region, education and status). In the first set of simulations (plain dark line), we use the full version of the model, accounting for the estimated changes in the parameters between the sub-periods, in the second set of simulations (dotted dark line), we use an alternative version of the model with no changes in the parameters, *i.e.* with the estimated second period effects ($\hat{a}_{Q,2007}$, $\hat{a}_{P,2007}$ and $\hat{a}_{V,2007}$) set to zero. The second set of simulations thus corresponds to a counterfactual situation where farmers' investment behaviour, and especially farmers' risk preferences, do not change over time. We can first notice, by comparing the light and dark plain lines on Figure 2, that the investment levels simulated with the full version of the model are very close to the observed levels, which demonstrates a good predictive performance of our model. The simulation results of the model without change in behaviour are, of course, identical to those of the full model in the first sub-period, but show a strong decrease in farm investments in the second sub-period. This decrease can be attributed to the increase in output price volatility that would have discouraged risk averse farmers to invest, despite the increase in output price level.

Figure 2: Observed and simulated investment levels over the period 2002-2014



Source: The authors based on FADN data.

5. Conclusion

We investigated the investment response of French crop farmers to changes in prices (investment price; and output price, both in levels and volatility) during the period 2002-2014. Focusing on large investors among farms specialised in cereals, oilseeds and protein seeds from the French FADN database, we estimated an econometric model of farm investment accounting for risk aversion and using a Hausman-Taylor estimation framework enabling to control for farmer's heterogeneity.

Our estimation results reveal a change in farm investment behaviour over time for large investments. More precisely, we find farmers to be risk averse in the first sub-period of our data, namely between 2002 and 2007, and risk neutral in the second sub-period (2008-2014). Yet, this second sub-period is characterised by a higher level of price volatility on crop markets, compared to the first sub-period. As shown by our simulation results, without change in farmers' risk preference between both sub-periods, this increase in price volatility would have induced a significant decrease in farm investments. The results we find for the first sub-period corroborate those of Sckokai and Moro (2009) who find price uncertainty to have a significant negative impact on farm investment over the period 1994-2003. However, these results lead the authors to conclude that an increase in output price volatility due to a removal of intervention price would decrease farm investment. Our article sheds a new light on that issue by showing that, for various reasons such as the socio-demographic evolution of farms, farmers' risk preferences have in fact been different in the recently observed context of uncertainty on crop markets, leading to a relative stability of farm investment across both sub-periods.

The small change in farmers' investment behaviour may be explained by the fact that farmers may have adapted their behaviour to the new context of uncertainty on crop markets. Also, the increase in crop prices, and hence in crop farm income, observed after 2007 may have led farmers to invest for other motives than increasing their production factors, given the tax exemption policy applicable to farm investments in France during the period studied here. The result that farmers become risk neutral in the second sub-period characterised by a higher level of price volatility on crop markets, may be counterintuitive. Although one explanation may lie in the fact that the second sub-period is also characterised by higher output price, further research in behavioural economics is necessary to understand farmers' changes in risk attitudes.

There are several other avenues for future research on farm investment decisions. First, the assumption of naïve expectations constrains the model to a static one. Modelling other types of expectations includes more complexity in the model but may also make it more flexible. In addition, the changes in economic conditions on crop markets might have generated a change in expectation schemes that appears as a change in risk preferences in our model. As shown by Manski (2004), the two elements are indeed difficult to distinguish. When data are available on a longer period and enable the use of time series data, one could estimate the investment model developed here under the assumption of quasi-rational expectations (Nerlove *et al.*, 2014). In this scheme, farmers form their expectations on a series of past observations. In this context, it would be interesting to test whether farmers' expectations become quasi-rational in the period with high output price volatility. A second development may be to consider the case of low investments. In this article we present findings that are specific to farmers implementing large (expansionary) investments, and cannot be generalised to all levels of investments, as farmers' economic behaviour may be different for low (replacement) investments. One interesting issue is that low investment may actually be driven by other factors than those related to the level and uncertainty on market prices that appear to have a significant impact on large investments. These types of investment may thus have evolved differently, and for other reasons between the two sub-periods. Investigating this issue would require a specific modelling of adjustment costs as in Gardebroek (2004), or a threshold regression method with various regimes allowing to characterize different types of investment as in Serra *et al.* (2009).

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