Responsiveness of farm investment to price changes: An empirical study of the French crop sector

Fabienne Femenia[1], Laure Latruffe[1], Jean-Paul Chavas[2]

[1] UMR SMART-LERECO, INRA, Rennes, France

[2] University of Wisconsin, Madison, United States

Contribution presented at the XV EAAE Congress, "Towards Sustainable Agri-food Systems: Balancing Between Markets and Society"

August 29th – September 1st, 2017

Parma, Italy

Responsiveness of farm investment to price changes: An empirical study of the French crop sector

Abstract

Understanding how farmers respond to prices can shed light into investment behavior and inform policy makers. We investigate the investment behavior of French crop farmers between 2002 and 2014, with a focus on adjustments to market prices. The analysis relies on a structural investment model derived from the maximization of farmers' future expected profit. Our estimation results show evidence of significant changes in investment behavior over time, farmers' investment being more responsive to output price before 2006, and to investment price from 2007. This suggests that government intervention through investment price may have positive impacts during periods of price volatility.

Keywords: investment; expectations; prices; crop farms; France

1 Introduction

Farm investment in agriculture is crucial to improve farm competitiveness, sustainability and resilience (EC & EIB, 2016). 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 to encourage farmers to invest is therefore crucial for policy-makers. Farmers' investment decisions are influenced by investment prices (lower prices would encourage investment), as well as output prices (higher prices would encourage investment to produce more). There exist public policies directly targeting investment, e.g. subsidies for implementing specific investment projects (such as the Rural Development Policy of the European Union-EU) or tax policies linked to investment (such as the French "*déduction fiscale pour investissement*"-DPI, allowing a reduction of taxes on farm revenue when investing). Those policies basically aim at decreasing investment costs. Other policies may influence farmers' investment decisions indirectly, through their impacts on market prices. It should however be noticed that, in most developed countries and in particular the EU, direct intervention on output market prices has been progressively replaced by payments decoupled from production and prices. It thus appears difficult to provide investment incentives to farmers through that channel. The responses of farm investment to output prices thus appear to be essentially market oriented and more difficult to control for policy-makers than responses to investment prices. One question is whether subsidies provided to farmers are effective (existing studies report mixed conclusions, see e.g. Bojnec and Latruffe, 2011; Viaggi et al., 2011), and another question is whether farmers are sufficiently responsive to changes in investment prices. We contribute here to the second question by comparing farmers' responses to changes in investment prices and in output prices for a sample of French crop farms specialized in cereals, oilseeds and protein seeds during the 2002-2014 period.

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 Morisson (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 under different assumptions regarding firms' expectations. Her 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 Vassavada 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, compare the sensitivity of investment to output price to its sensitivity to public payments, and find investment to be more sensitive to output price in periods of favorable economic situation (i.e. increase in capital stocks) and more sensitive to government support in the case of difficult economic situation. These authors do not, however, study the sensitivity of investment to its own price. Our paper contributes to this literature by investigating the responsiveness of farmers to both investment and output prices, using recent data and accounting for the recent increase in food price volatility.

The remainder of the paper is structured as follows. The next section explains the modelling framework. The third section describes the data and estimation strategies. The fourth section presents the results and the fifth section concludes.

2 The modelling of farmers' investment decisions: theoretical framework

To investigate farmers' investment decisions, two types of models are generally used in the literature. The primal approach relies on a structural model obtained from the maximization of future expected profit, under technological constraints. In this case, Euler equations are derived: they show the optimal path of investment from the current period onwards based on expectations of future profit. Gardebroeck (2004) and Gardebroeck and Oude Lansink (2004) are examples of works using this approach. The second approach is the dual approach, introduced by Epstein (1981). The producer's decision is represented by a value function, and the models are obtained from Hamilton-Jacobi-Belman equations. Examples of this approach include Oude Lansink and Stefanou (1997), Pietola and Myers (2000) and Sckokai and Moro (2009).

Here we follow the first approach involving an explicit representation of the production technology. Our modelling framework starts with a general investment model as in Chirinko (1993). We consider an agricultural producer *i* who, at period *t*, takes his/her production and investment decisions so as to maximize the present value (*PV*) of expected payoff on his/her farm, *i.e.* the expected sum of all his/her future discounted profits, subject to a capital accumulation constraint:

$$\max_{x,k,I} PV_{i,t} = E_{it}\left\{\sum_{s=t}^{\propto}\left(\frac{1}{1+r}\right)^{s-t}\left(p_{i,s}f(x_{i,s},k_{i,s}) - w_{i,s}x_{i,s} - \varphi(I_{i,s}) - PI_{i,s}I_{i,s}\right)\right\} \quad (1)$$

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

Where:

$E_{i,t}\{\}$ is the expectation operator: it corresponds to the expectations of farmer *i* given the information available to him/her at time *t*.

$x_{i,t}$ is the quantity of variable input used at period *t* and $k_{i,t}$ is the capital stock. These two inputs are combined, through a production technology $f(x,k)$ to produce a single output that is sold. At each time period, the capital stock depreciates at a rate δ and increases with new investment $I_{i,t}$. These new investments are subject to adjustment costs which we assume to be an increasing function $\varphi(I)$ of investment.

$p_{i,t}$, $w_{i,t}$ and $PI_{i,t}$ correspond respectively to the prices of output, input and investment. At the time where the producer takes his/her decisions (time *t*), he/she observes $w_{i,t}$ and $PI_{i,t}$ and has to form expectations about $p_{i,t}$ and $p_{i,s}$, $w_{i,s}$ and $PI_{i,s}$ for $s > t$.

r is a discount rate.

This optimization problem can be formulated as a stochastic dynamic problem where Bellman's equation takes the form:

$$V_{i,t}[k_{i,t}] = \max_{x_{i,t}, I_{i,t}} \left\{ E_{i,t}\{p_{i,t}f(x_{i,t},k_{i,t}) - \varphi(I_{i,t}) - w_{i,t}x_{i,t} - PI_{i,t}I_{i,t}\} + \left(\frac{1}{1+r}\right) E_{i,t}\{V_{i,t+1}[(1-\delta)k_{i,t} + I_{i,t}]\} \right\} \tag{2}$$

It should be noted here that at the time of taking his/her production and investment decisions, the farmer observes the purchasing prices of investment and variable input for period *t*, hence $E_{i,t}\{PI_{i,t}\} = PI_{i,t}$ and $E_{i,t}\{w_{i,t}\} = w_{i,t}$. However, he/she has to form expectation about his/her productivity and output price at period *t*.

From equation (2) we can derive the first order conditions determining the optimal level of investment at period *t*:

$$E_{i,t}\{p_{i,t}f_k(x_{i,t},k_{i,t})\} + \left(\frac{1-\delta}{1+r}\right) E_{i,t}\left\{\frac{\partial V_{i,t+1}}{\partial k_{i,t}}\right\} = PI_{i,t} + \varphi_I(I_{i,t}) \tag{3}$$

with $\varphi_I()$ denoting the first derivative of adjustment costs with respect to investment. Equation (3) equates the sum of the current and future expected marginal value of capital to the current cost of acquiring new capital.

An expression of $\left(\frac{1-\delta}{1+r}\right) E_{i,t}\left\{\frac{\partial V_{i,t+1}}{\partial k_{i,t}}\right\}$ can be derived by proceeding recursively. Taking the derivative of equation (2) with respect to $k_{i,t}$ and applying the envelope theorem, we have:

$$\frac{\partial V_{i,t}}{\partial k_{i,t}} = E_{i,t}\{p_{i,t}f_k(x_{i,t},k_{i,t})\} + \left(\frac{1-\delta}{1+r}\right) E_{i,t}\left\{\frac{\partial V_{i,t+1}}{\partial k_{i,t}}\right\} \tag{4}$$

For the next time period, equation (4) becomes:

$$\frac{\partial V_{i,t+1}}{\partial k_{i,t+1}} = E_{i,t+1}\{p_{i,t+1}f_k(x_{i,t+1},k_{i,t+1})\} + \left(\frac{1-\delta}{1+r}\right) E_{i,t+1}\left\{\frac{\partial V_{i,t+2}}{\partial k_{i,t+1}}\right\} \tag{5}$$

Taking the expectation of this expression and proceeding recursively yields

$$\left(\frac{1-\delta}{1+r}\right) E_{i,t}\left\{\frac{\partial V_{i,t+1}}{\partial k_{i,t}}\right\} = \sum_{s=1}^{\infty} \left(\frac{1-\delta}{1+r}\right)^s E_{i,t+1}\{p_{i,t+s}f_k(x_{i,t+s},k_{i,t+s})\} \tag{6}$$

Replacing the future expected marginal value product of capital by this expression in equation (3), we have:

$$E_{i,t}\{p_{i,t}f_k(x_{i,t},k_{i,t})\} + \sum_{s=1}^{\infty} \left(\frac{1-\delta}{1+r}\right)^s E_{i,t+1}\{p_{i,t+s}f_k(x_{i,t+s},k_{i,t+s})\} = PI_{i,t} + \varphi_I(I_{i,t}) \tag{7}$$

$$E_{i,t}\{\Gamma_{i,t}\} = \varphi_I(I_{i,t}) + PI_{i,t} \tag{8}$$

With

$$\Gamma_{i,t} = \sum_{s=0}^{\infty} \left(\frac{1-\delta}{1+r}\right)^s \gamma_{i,t+s} \tag{9}$$

$$\gamma_{i,t} = p_{i,t} f_k(x_{i,t}, k_{i,t}) \tag{10}$$

$\gamma_{i,t}$ is thus the value of the marginal productivity of capital at period *t*, and $E_{i,t}\{\Gamma_{i,t}\} = \sum_{s=0}^{\infty} \left(\frac{1-\delta}{1+r}\right)^s E_{i,t}\{\gamma_{i,t+s}\}$ corresponds the expected long run marginal value of capital.

Various assumptions regarding the way economic agents form their expectation can be found in the literature, the three most represented cases being the rational, naïve and quasi-rational expectations. In the case of rational expectations (Muth, 1961; Lucas, 1976), agents are assumed to have a perfect knowledge of markets functioning, and to use all information available to him/her to forecast the future. In that case, expectations are consistent with supply-demand conditions and anticipated supply/demand shocks, and their modelling requires a representation of both supply and demand functions to determine equilibrium market conditions. Naïve expectations imply that agents forecast that all future values of market variables will be the same as the values observed when making their decision. Thijssen (1996) investigates farmers' investment behavior under the rational and naïve expectation assumptions: using a reduced form profit function and individual panel data of Dutch dairy farms, he found that elasticities are consistent with the theory only in the case of naïve expectations. These results thus call for the naïve expectation assumption over the rational expectation one. The third type of expectations frequently found in the literature, the quasi-rational expectation schemes, assume that agents use a whole set of past observations to form their expectations (Nerlove et al., 2014): empirically, future values are predicted from time series models. The naïve and quasi-rational expectations, both based on past observations, are found by Chavas (1999, 2000) to be the most frequent expectation schemes in livestock farming, as a large proportion of production in the pork market is generated by producers having quasi-rational expectations (Chavas, 1999) and having naïve expectations in the case of the beef market (Chavas, 2000).

Modelling both supply and demand is complex and is out of the scope of the present study. In addition, from an empirical point of view, the estimation of quasi-rational expectations requires long time series data, which is not the case for the panel data sample used in our empirical application. For these reasons, and consistent with the literature explained above, we use the naïve expectation assumption and assume that farmers expect the last observed values of output price and marginal capital productivity to prevail in all future periods:

$$E_{i,t}\{\gamma_{i,t+s}\} = E_{i,t}\{\gamma_{i,t}\} = p_{i,t-1} f_k(x_{i,t-1}, k_{i,t-1}) \tag{11}$$

Given that $\frac{1-\delta}{1+r} < 1$ by assumption, we have $\sum_{s=0}^{\infty} \left(\frac{1-\delta}{1+r}\right)^s = \left(\frac{1+r}{\delta+r}\right)$ and the long run marginal value of capital simplifies to:

$$E_{i,t}\{\Gamma_{i,t}\} = \sum_{s=0}^{\infty} \left(\frac{1-\delta}{1+r}\right)^s E_{i,t}\{\gamma_{i,t+s}\} = \left(\frac{1+r}{\delta+r}\right) p_{i,t-1} f_k(x_{i,t-1}, k_{t-1}) \tag{12}$$

To derive an estimable model from equation (7), we need to make assumptions regarding the form of the capital adjustment cost and production functions. Following the widespread assumptions in the literature, we consider a quadratic capital adjustment cost function (equation (13)) and a Cobb Douglas production technology (equation (14)):

$$\varphi(I_{i,t}) = \theta + \beta I_{i,t} + \frac{\alpha}{2} {I_{i,t}}^2 \quad (13)$$

Where β and α are scalars, with $\alpha > 0$ to ensure the concavity of the function.

$$y_{i,t} = f(x_{i,t}, k_{i,t}) = a {k_{i,t}}^b {x_{i,t}}^c \quad (14)$$

Where a, b and c are scalars, with $a > 0$, $0 < b < 1$ and $0 < c < 1$.

Combining equations (8) and (12), and replacing the marginal capital adjustment cost and marginal capital productivity by their expression derived from equations (13) and (14), leads to the following investment decision equation:

$$I_{i,t} = -\frac{\beta}{\alpha} + \frac{b}{\alpha}\left(\frac{1+r}{\delta+r}\right)\frac{y_{i,t-1}}{k_{i,t-1}} p_{i,t-1} - \frac{1}{\alpha} PI_{i,t} \quad (15)$$

The investment of farmer in a specific period is thus determined by the discounted value of the productivity of capital in the previous period, and by the price of investment in the current period.

3 Data and estimation strategies

3.1. Data

We use a sample of farm-level data extracted from the French Farm Accountancy Data Network (FADN) for 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 specializations and regions. The French FADN database is a rotating panel with a rotation rate is about 10%, making the sample an unbalanced data sample. As investment types and levels may depend on production specializations, we focus here on a specific sample, namely farms specialized in the production of cereals, oilseeds and protein seeds.

We expect that low levels of investment may not be subject to the same adjustment costs than higher levels. Low levels of investment may show replacement investment, while high levels of investment may indicate expansionary or innovative investment. As suggested by Kapelko et al. (2016), replacement investment do not have the same adjustment process as the two other types of investment. For this reason, we select the farms investing the most, i.e. the farms displaying investment levels higher than the sample average. After cleaning the data and eliminating outliers, the total number of observations in our sample during 2002-2014 is 3,886 (approximately 300 farms per year).

The investment level (I) is an aggregate of machinery, building and land investments. As no price of investment (PI) 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. The price of wheat (calculated for each farm in each year using FADN data) in Euros per kilogram of wheat is taken as a proxy of the output price (p). The productivity of capital is the ratio of total output (excluding subsidies) (y) to fixed capital (k). The capital depreciation rate (δ) is fixed at 0.05[1] and the official annual interest rate provided by the European Central Bank is taken as the actualization rate (r). All values are measured at constant 2002 prices using the corresponding national price indices.

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

Figure 1 reports the evolution of the yearly averages of investment level, investment price and output price over our sample period. On the figure the annual values are not reported in levels, but as percentage differences compared to the average value for the full period. The first thing to note is that we observe two distinct sub-periods in terms of levels: in the first sub-period 2002-2006 investment levels and output price levels are lower than in the second sub-period 2007-2014. The second thing to note is that, while the investment price remains relatively stable during the whole period, the output price experiences ups and downs during the second sub-period. This conforms to the general knowledge that crop prices (here wheat prices) are higher on average and much more volatile since 2007. The third point to notice on Figure 1 is that, during the second sub-period, farm investment does not follow the same evolution as output price. All this suggests that farmers' investment responses to prices may not be the same during both sub-periods. For this reason, we will estimate our model not only for the whole period, but also for two sub-periods: 2002-2006 and 2007-2014.

Table 1 provides descriptive statistics of our variables of interest for the whole 2002-2014 period and for the two sub-periods. During 2002-2014 the cereals, oilseeds and protein seeds farms in our sample operated on average 159 hectares (ha) of utilized agricultural area and used 1,517 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, the structural characteristics of the two sub-samples (in 2002-2006 and in 2007-2004) are similar. Hence, the discrepancies in investment levels and evolution across both sub-period observed on Figure 1 reveal a change in investment behavior across sub-periods, rather than a difference in the composition of sub-samples across sub-periods.

About half of the sample farms are of individual (sole proprietorship) legal status, compared to partnerships or companies. About half of the farms are located in the wide Parisian basin area (administrative regions "Ille-de-France", "Picardie", "Champagne-Ardennes" and "Centre"), which is the main area for wheat production in France, while 16% 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 exhibit specific characteristics for field crop farms, the Parisian basin being a region with particularly good cropping conditions and large farms, and the South West of France being largely composed of farms specialized in irrigated corn production.

On average during the whole period, farms produced an output of 1,028 Euros per ha per year and invested on average 415 Euros per ha each year (the minimum being 160 and the maximum 3,620 Euros). Table 1 clearly shows that output and investment are lower on average during the first sub-period than during the second sub-period. In addition, 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 (143 vs. 104 Euros per ton of wheat).

3.2. Estimation strategies

We seek to estimate the following econometric model, based on the theoretical model of farmers' investment choices defined by equation (15):

$$I_{i,t} = a_0 + a_Z{}'Z_{i,t} + a_T Trend_t + a_{PK} ProdK_{i,t-1} + a_{PI} PI_{i,t} + u_i + \varepsilon_{i,t} \qquad (16)$$

Where $\varepsilon_{i,t}$ is the random error, and the a are parameters to be estimated.

The $ProdK_{i,t-1}$ variable in equation (16) denotes the discounted value of the capital productivity in period *t-1* in equation (15): $Prod_{i,t-1} = \left(\frac{1+r}{\delta+r}\right)\frac{y_{i,t-1}}{k_{i,t-1}} p_{i,t-1}$.

$Z_{i,t}$ is a matrix composed of three dummy variable vectors representing farmers' characteristics and used to partly control for the heterogeneity in investment levels among farms. These variables include the legal status of the farm, which takes the value 1 for individual farms and 0 for partnership farms and companies; and two regional variables: the first one takes the value 1 for farms located in the large Parisian basin area (defined above) and 0 otherwise, the second one takes the value 1 for farms located in the South West of France (defined above). A trend variable is also included in order to account for the evolution of investment with time: the $Trend_t$ variable takes the value 1 for the first year of observation and increases by one unit each year.

We also introduce an individual random effect u_i to control for the unobserved heterogeneity in investment levels. This random effect is assumed to be independent from the error of the model, $\varepsilon_{i,t}$. Moreover, different unobserved factors 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 part of the model and the productivity variable, which would lead to biased estimates, we apply the Hausman-Taylor (1981) instrumental variable approach.

Our objective is to obtain a value of the parameters for the capital adjustment cost function (α and β) and for the production technology (b) in order to compute investment elasticities with respect to output and investment prices. The value of these parameters can easily be recovered from the estimated coefficients a of our econometric model (16), as shown in equations (17)-(19), while their significance can be computed through the delta method.

$$\hat{\alpha} = -\frac{1}{\widehat{a_{PI}}} \tag{17}$$

$$\hat{\beta}_{it} = \frac{[\widehat{a_0} + \widehat{a_Z}' Z_{i,t} + \widehat{a_T} Trend_t]}{\widehat{a_{PI}}} \tag{18}$$

$$\hat{b} = -\frac{\widehat{a_{PK}}}{\widehat{a_{PI}}} \tag{19}$$

These parameters allow to compute the elasticities of investment with respect to the investment and output prices. The elasticity of investment with respect to the (observed) price of investment ($eIPI_{it}$) and the elasticity of investment with respect to the (expected) price of output ($eIPI_{it}$) are respectively:

$$eIPI_{it} = \frac{\partial I_{it}}{\partial PI_{it}} \frac{PI_{it}}{I_{it}} = -\frac{1}{\hat{\alpha}} \frac{PI_{it}}{I_{it}} \tag{20}$$

$$eIP_{it} = \frac{\partial I_{it}}{\partial p_{it-1}} \frac{p_{it-1}}{I_{it}} = \frac{\hat{b}}{\hat{\alpha}} \left(\frac{1+r}{\delta+r}\right) \frac{p_{it-1} y_{it-1}}{k_{it-1} I_{it}} \tag{21}$$

4 Results

Table 2 reports the regression results of the estimation of the investment model in equation (16) for the whole period 2002-2014 as well as for the two sub-periods. The three models show that many parameters are statistically significant. In the whole period and also in both sub-periods, the main variables of interest have the expected sign: positive for the value of capital productivity in the previous period and negative for the price of investment. Consistent across both sub-periods and for the whole period is the fact that individual farms invest more per ha than partnerships and companies. Some differences can be noted with respect to the regional dummies and the time trend. During the whole period only farms in South Western France invest less per ha on average than the other farms, while in the first sub-period there is no difference in investment behavior across France, and in the second sub-period farms in both areas considered invest less per ha than the other farms in France. As for the trend variable, it is positive and significant for the whole period, but not significant during the second sub-period, confirming the saw tooth evolution for this sub-period observed on Figure 1. The trend has a significant negative effect in the first sub-period, supporting the slight decrease observed on Figure 1 for this period.

The coefficients reported in Table 2, as well as the variance-covariance matrices (not reported), enable us to calculate the value (equations (17)-(19)) and the significance of the parameters that underlie the investment decision, namely the parameters for the capital adjustment costs function and for the production technology. Table 3 shows the values and significance of these parameters. Some conditions on parameters are necessary for the models to be well behaved: the α parameter has to be positive for the capital adjustment cost function to be convex. Also, for the adjustment costs to be increasing in investment, i.e. for the derivative of the cost function with respect to investment, φ_I, to be positive, the following has to hold: $I_t > -\frac{\beta}{\alpha}$. Finally, one expects the b parameter of the production function, which corresponds to the elasticity of production with respect to capital, to take values between 0 and 1. Table 3 shows that the conditions on α and b are fulfilled in all periods. By contrast, the negative value of β estimated here could imply decreasing adjustment costs up to a certain investment level. However, the β's are not significant at the 5% level, suggesting that there are in fact no decreasing adjustment costs and that the function is always upward sloping.

The elasticities, computed with the parameters of Table 3 for each observation, are reported in Table 4 as averages for the sample. Both elasticities, with respect to the price of investment and with respect to the price of output, are significant in all periods considered and have the expected sign: investment decreases with the price of investment and increases with the price of output. The first result to note is that the elasticity with respect to the price of investment is on average the same in the whole period (-0.22) and in both sub-periods (-0.25 and -0.23). This is not the case for the elasticity with respect to the price of output: its average value is 0.14 for the whole period, while it is 0.56 for the first sub-period and 0.20 for the second sub-period. The second result is that the elasticity with respect to output price decreases between the first sub-period and the second sub-period. While in the first sub-period, it was much above the elasticity with respect to investment price, both elasticities have a similar range during the second sub-period. This reveals that in the first sub-period farmers were more responsive to changes in the expected output price than in the investment price, while in the second sub-period they were equally responsive.

5 Conclusion

We investigated the investment response of French farmers to changes in prices (investment price and output price) during the period 2002-2014. Understanding whether farmers are more responsive to one or the other price can help draw policy recommendations regarding incentives for farmers' investment. We used a structural model obtained from the maximization of farmers' future expected profit under naïve expectations and a Hausman-Taylor estimation framework enabling to control for farmer's heterogeneity. We applied the estimation to large investors in the sample of cereals, oilseeds and protein seeds farms from the French FADN database.

We found that the period considered is composed of two sub-periods in which farmers' behavior was different. The first sub-period between 2002 and 2006 is characterized by stable output prices, and relatively stable investment. By contrast, the second sub-period between 2007 and 2014 is characterized by higher but more volatile output prices, and similarly by higher but more volatile levels of investment. The different price evolutions between both sub-periods indicate the date where output prices became more volatile. In a context of higher price volatility and hence higher uncertainty of expected profitability of investment projects, the behavior of agents regarding irreversible investment is affected. In agriculture, irreversibility is strongly present as capital is often production specific and may not be used for alternative uses. In theory, the situation of price volatility (uncertainty) combined with investment irreversibility should make agents invest less and delay investment decisions (Dixit and Pindyck, 1994; Sckokai and Moro, 2009). However, this is not what we observe in our data. This may be explained by the fact that in such context agents may continue to invest but do so in more malleable technologies, that is to say technologies that are more easily reversed (Cavallo et al., 2013). Another explanation is that uncertainty increases the expected return of the investment project, and hence the threshold price that would trigger investment (Dong et al., 2016). Here, although the output price is more volatile after 2007, its level remains high during this sub-period, and probably sufficiently high to prompt large investments. Finally, high investments in the presence of price volatility may be explained by farmers changing their output mix in order to produce crops that are less risky (Sckokai and Moro, 2009). Such changes in output mix may require specific investments.

In the first sub-period between 2002 and 2006, farmers' average investment levels slightly decrease with a continuous trend, and farmers' investment behavior is more responsive to the price of output than to the price of investment. By contrast, in the second sub-period between 2007 and 2014, farmers' investment behavior is more erratic and is as much responsive to the price of output as to the price of investment. Since the responsiveness with respect to investment price is very stable across both periods, the results show that it is the output price that makes farmers' behavior change. As explained above, this may be due to the increase in output price levels during the second sub-period.

On a policy point of view, our investigations suggest that during periods of stable output prices, the level of expected output prices strongly affects farmers' behavior, more than the level of investment price. However, this is not the case anymore when prices become volatile. Providing that farmers have naïve price expectations, our results suggest that in the current context of crop prices volatility, farmers' investment behavior may not be as influenced as it was before by output prices. By contrast, governments could influence farmers' investment through intervention on investment prices.

On a methodological point of view, our analysis underlines the need to carefully model the expectations scheme. The choice of the form of expectations is indeed a crucial issue. As shown here, expectations play a role in investment decisions, in the way that production and investment choices are based on expected future profit. To make his/her decisions, the farmer observes input prices and investment cost in the current period, and has to forecast the output price, as well as the future evolution of input prices and investment cost in the next periods. Farmers' response in terms of capital adjustments following a policy change depends on farmers' expectations of the effects of the policy change. For instance, using a Computable General Equilibrium model, Femenia and Gohin (2013) show that the impact of an agricultural policy reform on economic welfare partly depends the way agents form their expectation. More specifically, the way agricultural producers adjust their capital stock to adapt their production after the reform depends on their expectations of the impacts of the reform on market conditions: if they have an imperfect knowledge of the structure of the economy and do not immediately anticipate the impacts of the reform in order to consequently adjust their production, the reform can initially generate welfare losses. 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. 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.

Acknowledgements

The French FADN data are provided by the "Service de la statistique et de la prospective" in the French Ministry of Agriculture. The use of the French FADN data and the contents of this article are the sole responsibility of its authors. The authors thank Yann Desjeux for his help in processing the data. This work is supported by a public grant overseen by the French National Research Agency (ANR) as part of the "Investissements d'Avenir" program (reference: ANR-10-EQPX-17-Centre d'accès sécurisé aux données–CASD).

6 References

Bojnec, S. and Latruffe, L. (2011). Financing availability and investment decisions of Slovenian farms during the transition to a market economy. *Journal of Applied Economics*, 14(2): 297-317.

Cavallo, E., Galindo, A., Izquierdo, A. and Jairo León, J. (2013). The role of relative price volatility in the efficiency of investment allocation. *Journal of International Money and Finance*, 33: 1-18

Chavas, J. P. (2000). On information and market dynamics: the case of the US beef market. *Journal of Economic Dynamics and Control*, 24(5): 833-853.

Chavas, J. P. (1999). On the economic rationality of market participants: the case of expectations in the US pork market. *Journal of Agricultural and Resource Economics*, 24(1): 19-37.

Chirinko, R. S. (1993). Business fixed investment spending: Modeling strategies, empirical results, and policy implications. *Journal of Economic Literature*, 31(4): 1875-1911.

Dixit, A.K. and Pindyck, R.S. (1994). *Investment under Uncertainty*. Princeton University Press, Princeton, United States.

Dong, F., Hennessy, D. A., Jensen, H. H. and Volpe, R. J. (2016). Technical efficiency, herd size, and exit intentions in U.S. dairy farms. *Agricultural Economics*, 47(5): 533-545.

EC & EIB (2016). Mobilising Funds for Farming in Europe. Investment Plan for Europe. Fact Sheet, European Commission and European Investment Bank. https://ec.europa.eu/priorities/sites/beta-political/files/investment-plan_sector_specific_factsheet_agri_online_en.pdf

Epstein, L. G. (1981). Duality theory and functional forms for dynamic factor demands. *The Review of Economic Studies*, 48(1): 81-95.

Gardebroek, C. (2004). Capital adjustment patterns on Dutch pig farms. *European Review of Agricultural Economics*, 31(1): 39-59.

Gardebroek, C. and Oude Lansink, A. (2004). Farm-specific Adjustment Costs in Dutch Pig Farming. *Journal of Agricultural Economics*, 55(1): 3-24.

Femenia, F. and Gohin, A. (2013). On the optimal implementation of agricultural policy reforms. *Journal of Policy Modeling*, 35(1): 61-74.

Hausman, J. A. and Taylor, W. E. (1981). Panel data and unobservable individual effects. *Econometrica*, 49(6): 1377-1398.

Kapelko, M., Oude Lansink, A. and Stefanou, S. E. (2016). Investment age and dynamic productivity growth in the Spanish food processing industry. *American Journal of Agricultural Economics*, 98(3): 946-961.

Lucas, R. E. (1976). Econometric policy evaluation: A critique. In: *Carnegie-Rochester conference series on public policy (Vol. 1)*, North-Holland, 19-46

Morrison, C. J. (1986). Structural models of dynamic factor demands with nonstatic expectations: an empirical assessment of alternative expectations specifications. *International Economic Review*, 27(2): 365-386.

Muth, J. F. (1961). Rational expectations and the theory of price movements. *Econometrica*, 29(3): 315-335.

Nerlove, M., Grether, D. M. and Carvalho, J. L. (2014). *Analysis of economic time series: a synthesis*. Academic Press.

Oude Lansink, A. and Stefanou, S. E. (1997). Asymmetric adjustment of dynamic factors at the firm level. *American Journal of Agricultural Economics*, 79(4): 1340-1351.

Pietola, K. S. and Myers, R. J. (2000). Investment under uncertainty and dynamic adjustment in the Finnish pork industry. *American Journal of Agricultural Economics*, 82(4): 956-967.

Sckokai, P. and Moro, D. (2009). Modelling the impact of the CAP Single Farm Payment on farm investment and output. *European Review of Agricultural Economics*, 36(3): 395-423.

Serra, T., Stefanou, S., Gil, J. M., and Featherstone, A. (2009). Investment rigidity and policy measures. *European Review of Agricultural Economics*, 36(1): 103-120.

Thijssen, G. (1996). Farmers' investment behavior: An empirical assessment of two specifications of expectations. *American Journal of Agricultural Economics*, 78(1): 166-174.

Vasavada, U. and Chambers, R. G. (1986). Investment in US agriculture. *American Journal of Agricultural Economics*, 68(4): 950-960.

Viaggi, D., Raggi, M., Gomez y Paloma, S. (2011). Understanding the determinants of investment reactions to decoupling of the Common Agricultural Policy. *Land Use Policy*, 28(3): 495-505.

7 Tables and Figures

Table 1. Descriptive statistics of the sample used

		Whole period		2002-2006		2007-2014	
		Mean	S. D.	Mean	S. D.	Mean	S. D.
Total utilized agricultural area (ha)		159	87	160	85	158	88
Capital (Euros/ha)	k	1,517	1,028	1,562	1,126	1,448	954
Output (Euros/ha)	y	1,028	638	883	548	1,124	678
Gross investment (Euros/ha)	I	415	292	375	270	444	303
Wheat price (Euros/ton)	p	128	28	104	14	143	30
Investment price	PI	0.114	0.079	0.112	0.078	0.114	0.080
Depreciation rate	δ	0.05	0	0.05	0	0.05	0
Actualization rate	r	0.023	0.036	0.023	0.036	0.023	0.036
		%		%		%	
Share of farms with individual legal status		51		53		49	
Share of farms in Parisian basin region		47		50		46	
Share of farms in South West region		16		16		16	
Number of observations		3,886		1,543		2,343	

Source: The authors based on French FADN data.

Table 2. Regression results of the investment model

	Whole period	2002-2006	2007-2014
Constant term (a_0)	390.46***	218.12***	440.22***
Dummy variables (a_Z)			
Individual legal status	77.47***	139.61***	87.94***
Parisian basin area	-15.46	25.88	-29.49*
South Western France	-37.41**	-30.31	-38.33*
Time trend (a_T)	2.93*	-9.16*	-1.75
Value of capital productivity in t-1 (a_{PK})	22.34***	140.44***	25.51***
Price of investment (a_{PI})	-601.96***	-627.29***	-661.95***
Wald Chi-square statistic	174***	58***	98***
Number of observations	3,776	1,511	2,265

*Significance levels: * 10%, ** 5%, *** 1%*
Source: The authors based on French FADN data.

Table 3. Values and significance of the investment decision parameters

Parameters for		Whole period	2002-2006	2007-2014
Capital adjustment cost function	$\hat{\alpha}$	0.0017*** (0.0001)	0.0016*** (0.0003)	0.0015*** (0.0002)
	$\bar{\beta}$	-0.74* (0.64)	-0.42 (1.78)	-0.70 (1.15)
Production technology	$\hat{b}$	0.04*** (0.01)	0.22*** (0.05)	0.04*** (0.01)

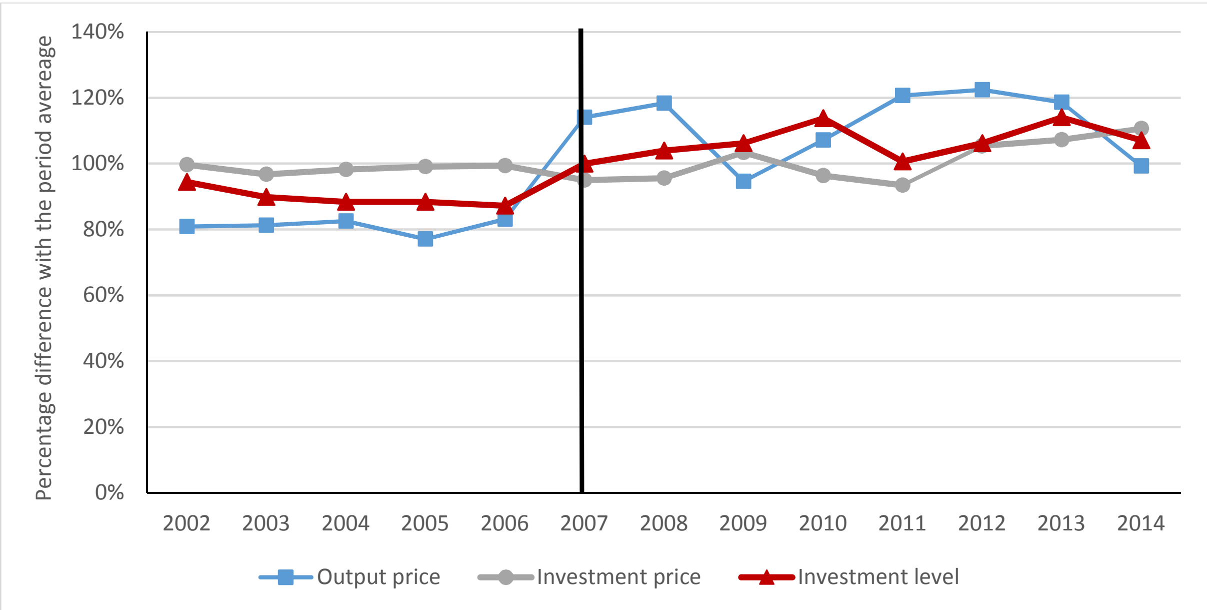
Standard deviations of estimates are in parentheses
*Significance levels: * 10%, ** 5%, *** 1%*
Note: the parameter $\bar{\beta}$ is the average value of the $\hat{\beta}_{it}$ over i and t.
Source: The authors based on French FADN data.

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

	Whole period	2002-2006	2007-2014
With respect to investment price ($eIPI_{it}$)	-0.22*** (0.02)	-0.25*** (0.03)	-0.23*** (0.02)
With respect to output price (eIP_{it})	0.14*** (0.02)	0.56*** (0.06)	0.20*** (0.02)

Standard deviations of estimates are in parentheses
*Significance levels: * 10%, ** 5%, *** 1%*
Source: The authors based on French FADN data.

Figure 1. Evolutions of the 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.