On the Nature and Magnitude of Cost Economies in Hog production*

Sabine Duvaleix-Tréguer[a] and Carl Gaigné[b,c]

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Abstract

In this paper, we assess the impact of farm size on production cost and evaluate the marginal costs and margins by considering that input prices may change with the scale of production. By using French hog farm data, we estimate a system of equations including a feed price function, input demand functions, and an output supply function based on a technology approximated by a combined generalized Leontief-Quadratic form. Our results suggest that the marginal costs are over-estimated when the endogeneity of feed prices is not controlled for. More specifically, cost economies for large farms (enjoying the highest profits) arise from feed prices and little by technological scale economies. In contrast, farms with no hired labour exhibit technological scale economies and reach higher price-cost margins than larger farms.

*Keywords***:** Marginal cost; Farm size; Scale economies; Input prices; Price-cost margin;
JEL Classification: Q12; D24

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[a] Agrocampus Ouest, UMR1302 SMART, 35000 Rennes (France). Email : sabine.treguer@agrocampus-ouest.fr
[b] INRA, UMR1302 SMART, 35000 Rennes (France). Email : carl.gaigne@rennes.inra.fr
[c] Université Laval, CREATE, Québec (Canada).

1. Introduction

For many countries, organization of the livestock sector is high on the agenda. Increasing international competition in this sector raises the question of evaluating the optimal structure of livestock farms, being aware that the optimal farm structure might vary over time and according to production systems. A key question concerns the relationship between farm size and its economic efficiency. In the last decades, we observed the development of large specialized production units in many developed countries in various livestock sectors (MacDonald *et al.*, 2010). This transformation suggests the presence of cost economies associated with farm size. However, in the empirical literature on the nature and magnitude of cost economies, much attention has been paid to technological factors, but little attention has been afforded to the role of market mechanisms. This paper argues that increasing the output size also enables farmers to pay a lower *unit* price of variable input when buying larger input quantities.

Traditionally, the fall in unit costs associated with the rise in production scale is explained by technological factors such as fixities imbedded in the technology or internal scale relationships. Indivisibilities in the production process imply fixed costs and hence economies of scale. Larger production provides an opportunity for spreading the fixed costs to more product units and, in turn, lowering unit costs. In addition, the large scale of operations may induce the better use of existing inputs. For example, an increasing level of operation may allow the farmer to improve the use of labour. More generally, the output may increase greater than in proportion to the inputs. Several earlier studies have analyzed scale economies in livestock farms in the U.S. (Key *et al.*, 2008; Kumbhakar, 1993; Moschini, 1988; Mosheim and Lovell, 2009; Nehring *et al.*, 2009; Tauer and Mishra, 2006) as well as in Europe (Alvarez and Arias, 2003; Fernandez-Cornejo *et al.*, 1992; Rasmussen, 2010). The evidence supporting scale economies is rather mixed–strong for livestock production (MacDonald and McBride, 2009).

However, unit costs may also decrease as the production scale increases because of lower *unit prices* of variable inputs. Several reasons may explain why the unit price of many products decreases with the purchased quantity (Beard *et al.*, 2007; Calzori and Denicolo, 2011). On the one hand, the input provider can supply progressive rebates on quantity to reduce some of the transaction costs in writing a contract and delivering the product. In addition, the supplier's technology may exhibit scale economies and pass them on to buyers through a lower unit price. Furthermore, such a price discrimination enables input providers to better extract purchaser surplus. Under these circumstances, there exists a menu of tariffs from which a customer can choose depending on his purchased volume. On the other hand, large buyers may also bargain to obtain a lower price. The possibility of achieving lower unit input prices depends not only on the ability of farmers to negotiate prices also on the gains that the supplier reaches from a larger individual demand.[1]

Once it is recognized that input suppliers practice non-linear pricing and/or a large producer may be able to bargain over the input price to take advantage of pecuniary economies, cost economies may be related not only to technology but also to market mechanisms. When cost economies are estimated, we should consider that the unit input price can vary with output size. The estimates may then be biased when the estimations are based on input demands and cost functions, because input prices may be correlated with the error term in the input demand equation.

In this paper, we evaluate the impact of the output size on the short-run production cost taking into account that the prices of some inputs may differ among farmers. More precisely, using a unique data set on French hog farms at the feeder-to-finish operation level, we estimate a system of equations based on a generalized Leontieff cost function developed by Morrison Paul (2001a) to evaluate the nature and magnitude of cost economies in hog production. Our system includes inputs demand and output supply functions as well as a unit feed input price equation to capture the ability of farmers to enjoy a lower unit price with respect to the quantity of purchased feed.

The literature in agricultural economics estimating cost economies neglects the pecuniary externalities affecting unit input prices. The literature estimating profit or cost functions considers that farmers do not purchase their factor inputs in bulk at discounted prices or do not bargain over the input price. If such an assumption is realistic concerning the output market, it is discussed for some of the inputs, such as feeds and fertilizers (Debertin 1986) and is related to the type of organization in the agricultural sectors. Indeed, even though French hog producers sell their production through producer organizations (Roguet and Rieu, 2011), this French collective organization conceals a wide diversity of hog producer organizations in their upstream and downstream partnerships. French hog producers keep a strong managerial autonomy in their production choices and may negotiate their input prices. More generally, Key (2005) showed that hog producers reveal a strong preference for

[1]It is worth stressing that we consider here that the buyer has no market power, *i.e.* he cannot manipulate the market price by changing his level of production (as under an oligopsonic market structure).

autonomy.

From a methodological standpoint, our results suggest that the marginal costs are over-estimated when the endogeneity of feed prices is not controlled for. In other words, cost economies associated with the scale of operation and price-cost margins might be under-estimated in the current literature on scale economies in agricultural production. Although our work cannot be generalized, we believe that our results are sufficiently convincing to warrant a greater focus on input price endogeneity in assessing cost economies.

Our study also provides a better understanding of the nature and magnitude of cost economies at the hog farm level. We show that hog farms face cost economies in the short run due to technological factors and to market mechanisms. Most farms face decreasing average costs even if their short-run marginal costs increase in hog production; hog farms are closed to their minimum average costs. More precisely, cost economies associated with output size are related to lower feed prices and not to a fall in the relative use of labour, regardless of estimations. The only source of scale economies in hog production seems to be related to feed input utilization. The gains associated with a better use of feed are stronger for the farms with no hired labour. These hog farms also reach higher price-cost margins than larger farms. *In fine,* there are technological scale economies, but the magnitude of cost economies associated with the scale of operation in hog production due to lower feed prices is significant. The negative effect of an increasing size on the unit feed price paid by the farmers allows them to significantly reduce their marginal costs by an average 2.4 € per head, which represents on average of approximately 7735 € per year and per farm.

We must stress here a major difference between our approach and the analysis in Morrison Paul (2001a,b). She considers large firms producing under imperfect competition and holding a market power (her study concerns the meat industry in the United States). In other words, in Morrison Paul, firms may manipulate the market price, and this price is the same for all firms. In our case, we do not consider that the existing farms can manipulate the market price by changing their production level, regardless of their size. We assume that farmers face different unit input prices with respect to the quantity of purchased input. Hence, the input prices paid by farmers may differ and are affected by the level of hog production.

This paper is also related to the empirical studies using data on hog producers. These contributions offer limited evidence on cost economies in this sector. From a stochastic frontier analysis, Key *et al.* (2008) show that the changes in total factor productivity growth in US hog farms can be explained by technical progress and improvements in scale efficiency. By testing the existence of stage-specific scale economies, Azzam and Skinner (2007) conclude that it is not cost effective to expand finished hog production for small farms while there are scale economies specific to the feeder-to-finish stage for large farms. However, as recognized by the authors, this study suffers from several caveats (the non-randomness of the sample, no farm-specific input prices, no control for heterogeneity, ...). Furthermore, when assessing the impact of farm size on production cost, the existing literature fails to address the adjustment of unit input price to a change in production. Hence, the estimates may be biased when the estimations are based on input demands and cost functions because input prices may be correlated with the error term in the input demand equation.

The paper is organized as follows. We develop in the next section the model that we test. We present data in section 3 whereas section 4 provides the results as well as a set of additional estimations to test the robustness of our results. The last section concludes.

2. A cost function-based model

In this section, we present the full decision process allowing us to identify cost economies when the level of input prices is not exogenous. First, as in the standard approach, farmers choose inputs to minimize costs under the technology constraint. As usual, we obtain the farm's conditional input demand functions where the levels of output, quasi-fixed inputs, and input prices are taken as given. Note that this cost minimization problem is the same regardless of whether the markets for the output good and for the inputs is competitive or if there are some market imperfections (see Morrison Paul, 1988, 2001b, for more details). Under these circumstances, the profit function of a hog producer is given by

$$\pi = pY - C(\mathrm{w}, Y, .) \tag{1}$$

where p is the unit price of hogs, Y is the number of hogs sold on the market, and $C(\mathrm{w}, Y, .)$ is the short-run production cost function with w is a vector of I variable inputs prices.

Second, we have to adapt the output supply decision. Traditionally, the producer chooses its output level by maximizing its profit π so that the equilibrium output is such that $p = \partial C / \partial Y$. However, as mentioned in the introduction, the unit price of inputs can depend on the level of production Y so that w can negatively react to a change in Y.

Hence, the farmer can adjust its level of production by taking into account the impact of Y on input prices and, in turn, on its profit.[2] Under this configuration, the equilibrium output is such that $p = \partial C / \partial Y + \Sigma_i (\partial C / \partial w_i)(\partial w_i / \partial Y)$.[3] Clearly, if we do not consider the input price adjustments to a change in the level of production, the marginal costs may be overestimated.

2.1 Technology and input demand

We assume that the farm's minimum cost of producing the output Y is characterized by a general form given by

$$C = G(\mathrm{w}, Y, \mathrm{x}, \mathrm{d}) \tag{2}$$

where w is a vector of I variable inputs prices (feed, labour and piglets with $i = f, l, p$ respectively), x is a vector of K quasi-fixed inputs (sows and capital with $k = s, c$ respectively), and d is a vector of control variables. The choice of these control variables is discussed when we present the equations we estimate. Note that we consider that labour is a variable input because we know the number of hours of labour at the finishing stage. We consider that G can be approximated by a combined generalized Leontief-Quadratic form (Morrison Paul 2001b) given by

$$G(\mathrm{w}, Y, \mathrm{x}, \mathrm{d}) = \Sigma_i \Sigma_j \alpha_{ij} w_i^{0.5} w_j^{0.5} + \Sigma_i \beta_i w_i Y + \Sigma_i \gamma_i w_i Y^2 + \Sigma_i \Sigma_k \delta_{ik} w_i x_k \tag{3}$$
$$+ \Sigma_i \Sigma_k \eta_{ik} w_i x_k Y + \Sigma_i \Sigma_k \Sigma_l \rho_{ikl} w_i x_k x_l + \Sigma_i \Sigma_r \mu_i w_i d_{ir}$$

where α_{ij}, β_i γ_i, δ_{ik}, η_{ik}, and ρ_{ikl}, and μ_i are the coefficients to be estimated (with $\alpha_{ij} = \alpha_{ij}$, $\delta_{ik} = \delta_{ki}$, and $\rho_{ikl} = \rho_{ilk}$) and d_{ir} represents the dummy variables (that we specify below). This flexible form can capture many aspects of cost economies through input substitutability, utilization rate of quasi-fixed input and scale economies. Apart from the advantages presented in Morrison (1988), this functional form allows us to deal with zero quasi-fixed input values.[4] It is worth noting that such a flexible functional form captures the

[2]Note that if the level of production affects the input price, the input demand can be obtained for a given input price as the input demand functions are determined by considering the production level as given.

[3]We could also consider the Nash outcome of the bargaining process involving two parties (the feed producer and the farmer). In a first stage, each farm independently bargains over its feed price with a feed producer and, in a second stage, each farmer sets the output and input demand to maximize profits by considering the feed price as given (equations (6) and (4)). However, our database does not allow us to implement a strategy such as that in Draganska *et al.* (2010) because we cannot identify the feed suppliers chosen by each farm and we do not have information on feed producers.

[4]Many studies on scale economies have chosen the translog function developed by Christensen Jorgensen and

cross-effects among all arguments of the cost function while the linear homogeneity in price is satisfied ($G(\lambda w,.) = \lambda G(w,.)$). In addition, there are no a priori restrictions on the shapes of curves representing technology. Because $\partial^2 G / \partial w_i^2$ is not ensured to be negative or, equivalently, $\alpha_{ij} > 0$ (global concavity) and $\partial^2 G / \partial x_k^2$ is not ensured to be positive or equivalently, $\rho_{ikk} > 0$ (convexity), we check *ex post* if $\alpha_{ij} > 0$ and $\rho_{ikk} > 0$.

We also characterize optimization decisions for the inputs and the output. By using Shepard's lemma, at the given level of output, the demand for each of the three variable inputs v_i $(= \partial G / \partial w_i)$ is expressed as

$$v_i = \alpha_{ii} + \alpha_{ij} w_i^{-0.5} \Sigma_{j \neq i} w_j^{0.5} + \beta_i Y + \gamma_i Y^2 + \Sigma_k \eta_{ik} x_k Y \qquad (4)$$
$$+ \Sigma_k \delta_{ik} x_k + \Sigma_k \Sigma_l \rho_{ikl} x_k x_l + \Sigma_r \mu_i d_{ir}.$$

We now clarify the dummy variables used in each input demand. As feed input represents over 60 percents of the hog production cost, hog producers develop several strategies. They first decide whether they produce their feed input on farm. Thus, we control for *On-Farm Feed* by using three categories: with only on-farm feed, with only purchased feed and both on-farm and purchased feed). Second, hog farms can use different types of feed diets, they decide whether they use a unique feed input or they adapt feed to the hog production stage in order to adjust feed composition (net energy and crude proteins) to each stage. To take into account feed quality, we use the *Feed Conversion Ratio* which is the total feed consumption over the gain in weight during the fattening duration as a proxy of feed quality. A low feed conversion ratio means that pigs from a farm consume less feed than pigs from another farm to reach the same weight. Thus the feed used to get a lower feed conversion ration contains either higher nutritional contents or attributes that facilitate feed intake. Third, we control for the *Producer Organizations* hog farmers belong to. About 90 percents of all hog farms are members of a producer organization. And each producer organization develops its own strategy as far as members services (feed, genetic, processing activities, ...) are regarded. Some producer organizations favour low feed prices, others prefer to give

Lau (1973) because this functional form makes easy to compute elasticities and facilitates the respect of homogeneity and regularity constraints but this functional form does not allow to get an analytical solution for the output level (see Alvarez and Aria, 2003 and Moschini, 1988 for estimation of scale economies in agriculture). Others have chosen the normalised quadratic function such as Fernandez-Cornejo et al. (1992). This function imposes to choose one input as the *numéraire* and thus it is treated differently from other inputs. As a consequence, both functions present shortcomings when conducting short-run analysis (see Morrison 1988 for a more complete discussion).

advises to better manage feed intake and get better technical results on hog farms.

In the labour input demand function, we mainly control for *Hired Labour*. In the piglet input demand function, we control for the *Specialization* of hog farms. Four types of hog farms according to their specialization stage are identified in the survey. We include them as control variables. We are more specifically interested in hog farms with sows as this production system is dominant in France. Finally in all input demand functions, we include dummy variables for the main hog production *Regions* (*Bretagne*, *Normandie*, *Pays de la Loire*).[5]

2.2 Input prices and output supply

To determine whether input prices depend on the level of production, we first test whether the farm size affects each input price through a simple OLS regression procedure by estimating the following equation for each input i price:

$$w_i = \sigma_{i0} + \sigma_{i1} Y + \sigma_{i2} Y^2 + \Sigma_r \mu_{ir} d_{ir} + \varepsilon_i. \tag{5}$$

where σ_{i0}, σ_{i1}, σ_{i2}, μ_{ir} are coefficients to be estimated and ε_i is an error term which independently and normally distributed. For the feed price equation, it is important to control for three main potential biases. First, hog producers get different feed prices because some of them produce their *On Farm Feed*, thus we include dummy variables to control for the hog producer's strategy. Second, the difference between feed prices paid by the farmers may reflect the difference in quality (difference in protein contents for example). As a result, we include the *Feed Conversion Ratio* as a proxy of feed quality. We expect it to be negatively correlated to feed input price as a low conversion feed ratio means a better feed intake and as a result a higher quality of feed.[6] Third, farmers may form purchasing alliances through producer organizations that buy in bulk to obtain quantity discounts. To control for this effect, we introduce a dummy variable indicating the *Producer Organization* to which a farmer belongs. We introduce 24 control variables to capture the individual effect of each producer organization. Finally, the feed prices may differ across regions because the regional demand for feed varies so that feed suppliers may benefit more and less from scale economies in feed production. In order to control for this potential bias, we have introduced a dummy for the main hog production *Regions*.

The results are reported in Table A.1 in Appendix A. Our findings show that the

[5]A *Region* is a French administrative area; there are 22 *Régions* in metropolitan France.
[6]We are aware that a low feed conversion ratio might also be reached by a combination of other factors such as farmer's skills and the management of sanitary conditions in hog farms.

parameters associated with the output size are not significant piglet price equations and in the labour price.[7] However, the level of production has a significant effect on the feed unit price. It appears that $\mathrm{d}w_f / \mathrm{d}Y = \sigma_{f1} + 2\sigma_{f2}Y < 0$. This suggests that the feed providers offer price reductions for bulk purchases. Because feed providers have market power due to scale economies and transport costs to reach farmers, they can charge customers with more elastic demands a lower price. In addition, the transaction costs incurred by feed suppliers are lower as farmers' purchases become larger, hog producers may negotiate lower feed unit prices according to their production scale. As a result, we append to the model a feed price equation to capture the impact of farm size on feed unit price, while the other input prices are considered exogenous.

In addition, we estimate the short-run supply function given by the maximization of the profit equation (1) under technological constraint (3) and by considering how the unit feed prices react to a change in hog production. The equilibrium output is implicitly given by $p = \partial C / \partial Y + \left(\partial C / \partial w_f\right)\left(\mathrm{d}w_f / \mathrm{d}Y\right)$. By using (5) and (3), we obtain

$$p = \Sigma_i \beta_i w_i + 2\Sigma_i \gamma_i w_i Y + \Sigma_i w_i \left(\Sigma_k \eta_{ik} x_k\right) + \Sigma_i \Sigma_r \mu_{ir} w_i d_{ir} + v_f \left(\sigma_{f1} + 2\sigma_{f2} Y\right). \quad (6)$$

In the supply equation, we control for the *Specialization* of hog farms, the *Producer Organization* the hog farm belongs to, the *Region* where the farm is located and the *Meat Quality* at the farm level through the lean meat percentage. We create a dummy for hog farmers who get a lean meat percentage greater than 61, that is when they obtain the highest premium.

2.3 Marginal costs, margins, and cost elasticities

The equations including the three derived demand equations (4), the supply function (6), and the feed price equation (5) are jointly estimated by full information. Using parameters α_{ij}, β_i γ_i, δ_{ik}, η_k, and ρ_{kl} as well as σ_{f1} and σ_{f2}, we can evaluate the marginal costs and margins as well as the cost-output relationship and the margin-output relationship.

It is both relevant and convenient to distinguish between the case under which feed prices paid by farmers do not react to a change in her/his operation scale and the configuration whereby unit feed prices adjust to farm size. Let MC be the short-run marginal cost for a given feed price with

[7] Labour price is slightly increasing in hog quantity at a 10% significance rate.

$$MC = \partial G / \partial Y = \Sigma_i w_i (\beta_i + 2\gamma_i Y + \Sigma_k \eta_{ik} x_k) \quad (7)$$

whereas the short-run margin is expressed as $p - MC$. We also use the short-run cost elasticity to a change in output ε_{CY} $(= \mathrm{d}\ln C / \mathrm{d}\ln Y)$ along the long-run cost curve where $\varepsilon_{CY} < 1$ means that average costs decrease with output.

In addition, let MC^e be the short-run marginal cost with an adjustment in unit feed price to a change in production, given by

$$MC^e = MC + \frac{\partial G}{\partial w_f}\frac{\partial w_f}{\partial Y} = \Sigma_i w_i (\beta_i + 2\gamma_i Y + \Sigma_k \eta_{ik} x_k) + v_f(\sigma_1 + 2\sigma_2 Y). \quad (8)$$

3. Data

We use data from a technical survey and a bookkeeping survey of hog farms conducted in 2006 by the French Institute of the Hog Sector (IFIP). These databases are unique as we get precise data on each *production stage* including technical and economic information. Furthermore, they are widely used as technical support for hog farms and widely widespread among producer organizations in France. In Appendix B, we show the participation rate in the databases for 2006 (see Map A.2).

Both surveys include a broad range of data on outputs, inputs, and management, as well as technical and social variables at the farrowing and finishing stages. Because we focus on scale economies in hog production, we only selected hog farms that operate the finishing stage of hog production and we excluded all farms that are specialized in the farrowing stage. In addition, only farms that had complete and reliable information for the selected outputs and inputs at the finishing stage are included in our database. Our sample has 772 French hog farms. For each farm, the survey provides the output quantity and hog price, the average feed price and quantity used at each stage as well as the feed cost when farmers make their own on-farm feed. We also get information on the number of sows, the piglet price when purchased by feeder-to-finish farms, and piglet production costs for farrow-to-finish farms. We also know the labour cost (family and hired labour) and the number of hours associated with hog production for each stage as well as whether the farm has hired labour. As a result, we can determine the unit labour cost (in € per hour). In addition, we know if the farm produces on-farm feed as well as the cost and quantity of on-farm feed.[8]

[8]The production costs are determined by the IFIP. They are commonly adopted by all the economic actors in

Table 1 provides some descriptive statistics on input prices (feed, labour and piglets) and output. The average price of hog is approximately 118 € per head, or 1.38 € per kilogram, which is close to the average price observed in France in 2006. The hog farms in our sample are heterogeneous in size, and the input prices differ among farms.

Table 1 about here

Most farms in our sample combine all the hog production stages, there are 581 farrow-to-finish farms (75% of farms in our sample), which is representative of the French hog sector. In addition, 494 farms buy all feed input to feed mills at an average price of 178 $€/T$, 186 farms exclusively produces on-farm feed at an average cost of 164 $€/T$, the remaining farms use both on-farm and purchased feed at an average price of 170 $€/T$. Furthermore, 443 farms do not employ any hired labour, their labour average price is 15.9 €/*hour* whereas the labour average price is 16.4 €/*hour* when hog farms use hired labour. Only 297 hog farms are located in the western part of France, the main hog production region including *Bretagne*, *Pays-de la Loire* and *Normandie*, which accounts for only 38% of all farms in our sample.

Table 2 about here

Table 2 reveals information about hog production costs and profits given by our databases, it shows that the average cost also varies greatly among farms. Figure 1 reveals that the average cost function has a L shape, which is common in the agriculture of developed countries (Chavas, 2001). The average cost declines with the production for small farms and, from a threshold value of hog production, remains relatively constant.

Figure 1 about here

4. Estimation and results

We estimate a system of five equations including the three input demand equations (4), the output supply equation (6) and the unit feed price equation (5) simultaneously. The last

the hog industry. The formula used to determine the different production costs are available on the IFIP web site (http://www.ifip.asso.fr/resultats-economiques-elevages-extranet-partenaires.html).

equation allows us to highlight the importance of endogeneity of input prices in assessing cost economies. In addition, because the error terms of these equations may be correlated and the feed demand and price are endogenous, we estimate the model using the three-stage least squares estimation method. We also use the control variables defined in Section 2 to take into account hog farm heterogeneity. The results for the estimated coefficients are reported in Appendix A.2. The generalized R^2 shows an excellent fit for the equation system (0.98). Despite the cross sectional nature of our data, the model provides a significant explanation of farmers' choices.

4.1 Regularity conditions and price effects

We first check whether our results are consistent. The estimated parameters must involve a cost function that satisfies the standard regularity conditions. Note that we check the regularity conditions at every data point and not at the sample mean. We must have $\partial^2 G / \partial w_i^2 < 0$ or, equivalently, $\partial v_i / \partial w_i = -0.5 w_i^{-1.5} \Sigma_{j \neq i} (\alpha_{ij} w_j^{0.5}) < 0$. All significant estimates $\hat{\alpha}_{ij}$ being positive (see Appendix A.2) and $w_i > 0$, the variable cost function is concave in w_i. In other words, at any given hog production, derived input demands are elastic to own-price changes (see Table 3). Further, we check that $\partial v_i / \partial Y > 0$, or equivalently, $\hat{\beta}_i + 2\hat{\gamma}_i Y + \Sigma_k \hat{\eta}_{ik} x_k > 0$. By inspection, we have $\partial v_i / \partial Y > 0$ for each observation (see Table 3 for the magnitude of the output supply elasticity of input demands). Hence, at any given input price, increasing the hog production involves a rise in input demands, as expected.

Table 3 about here

We check that an increasing output price leads to a rise in the output supply ($\partial Y / \partial p > 0$) and that an increase in input prices decreases the output supply ($\partial Y / \partial w_i < 0$). Using (6) and applying the envelop theorem gives

$$\frac{\partial Y}{\partial p} = \frac{1}{\partial^2 G / \partial Y^2} = \frac{1}{2\Sigma_i \hat{\gamma}_i w_i} \quad \text{and} \quad \frac{\partial Y}{\partial w_i} = -\frac{\partial^2 G}{\partial w_i \partial Y}\frac{\partial Y}{\partial p} = -\frac{\partial v_i}{\partial Y}\frac{\partial Y}{\partial p}. \quad (9)$$

Given the values of γ_i (see Appendix A.2) and w_i, we have $\Sigma_i \gamma_i w_i > 0$ for each farm so that $\partial Y / \partial p > 0$. In addition, because $\partial v_i / \partial Y > 0$ and $\partial Y / \partial p > 0$, we have $\partial Y / \partial w_i < 0$. Hence, demand and supply functions satisfy the conditions required by the theory.

4.2 Marginal costs, price-cost margins and cost economies

Table 4 reports the estimates of cost economies, marginal costs and profit margins. We first examine cost economies without taking into account the feed input price adjustment. By inspection, it appears that the estimated short-run marginal cost (given by MC) is positive at each observation. These results show that the short-run marginal cost is estimated at approximately 103.7 € per head whereas the average short-run margin is approximately 14.7 € per head (see Table 4) or 0.16 € per kg (the average hog weight being equal to 86 kilograms, see Table 1). At the sample mean of the data estimated, the cost elasticity ε_{CY} is 0.89, suggesting the presence of cost economies associated with output size. Some statistical tests indicate that the short-run cost elasticity is significantly below one for a wide range of observations. Thus, hog production is characterized by increasing returns to scale. Hence, we confirm the findings in Azzam and Skinner (2007) and Rasmussen (2011) from a different approach. By inspection, the estimated short-run marginal cost decreases with hog production. More precisely, the short-run marginal cost declines strongly for low values of hog production and slightly for high values of output (see Figure 2). These estimates suggest a flattening of the average cost curve for high levels of production (a L-shaped cost curve).

Table 4 about here

We now analyze the nature of cost economies. The fall in the marginal costs with output size may be due to a better input use or a decrease in unit feed price linked to a price rebate on input quantity between the largest hog farms and feed producers. We explore the cost economies that are related to the input use. Using (7), the impact of hog production on short-run marginal cost at constant input prices is given by $\partial MC / \partial Y = 2\Sigma_i \gamma_i w_i$, where $\gamma_i = \partial^2 v_i / \partial Y^2$. The coefficients associated with γ_i are given in Appendix A.2. It appears that farmers do not use less labour or less feed for each additional hog unit. In addition, they use relatively more piglets with the output size ($\hat{\gamma}_p > 0$). The estimated value of $\partial MC / \partial Y$ is positive for all farms and statistically different from zero. The values achieved by $\partial MC / \partial Y$ are low (0.0025 on average ranging from 0.0013 to 0.0063). Most farms face decreasing average costs, the cost elasticity ε_{CY} is less than one even if their short-run marginal costs are increasing in hog production. Thus, the size of hog production in each farm is closed to the hog production value that generates the minimum average costs.

Figure 2 about here

The cost economies are also related to the negative relationship between unit feed price and output size. Indeed, as expected, we have $\partial w_f / \partial Y = -0.026 + 7.66 \text{x} 10^{-7} Y$, which is negative by inspection for most observations. The feed price falls with hog production at a decreasing rate even if we control for the Producer Organization the hog farm belongs to, the Region where the farm is located, and the Feed Conversion Ratio. In addition, we can now evaluate the global impact of output supply on marginal costs by taking into account the adjustments in unit feed prices. The results are reported in Table 4. The marginal cost when the unit feed price reacts to hog production is estimated at approximately 101.2 € per head (1.19 € per kg). The average wedge between both short-run marginal costs is at approximately 2.4 € per head, an average of approximately 7735 € per year and per farm. It appears that the negative effect of an increasing size on feed price paid by the farmers (the elasticity $\varepsilon_{w_f Y}$ is negative and around -0.03) allows them to significantly reduce their marginal costs.

In other words, the cost economies associated with farm size are related to both scale economies and lower feed prices. Although feed price has a lower effect on cost economies than technology does, the impact of feed price is substantial. A mean comparison test between the short-run marginal cost (MC) and the short-run marginal cost with the feed price input adjustment (MC^e) indicates a significant difference between the means at the 0.01 level. On average, the feed price effect on marginal cost which is given by the derivative $\partial(MC^e - MC) / \partial Y$ accounts for 7.8% of the total cost economies generated by farm size which is given by the derivative $\partial MC^e / \partial Y$. Moreover, for few farms (1% in our sample), it represents approximately 32% of the total cost economies associated with farm size.

It is also worth stressing that the marginal costs and margins differ among farms according to their location. On average, the farms located in *Bretagne* (the Region specialized in hog production) exhibit lower marginal costs and higher margins than the other farms (see Table 5). This result seems to confirm the presence of agglomeration economies in the hog sector (Gaigné *et al.*, 2012) at the farm level. However, the nature and the magnitude of agglomeration economies at the farm level merit more attention. Exploring this question is beyond the scope of our analysis. This is an area for future research.

Table 5 about here

4.3 Robustness checks

Our results reveal that it is cost effective to expand hog production at the finishing stage. These cost economies not only are related to technology allowing farmers to use fewer inputs, but also seem to be associated with a lower unit feed price. We test whether such findings are robust. The production technology may differ among hog farms. Whenever heterogeneity among farms is not sufficiently controlled for, our results may be biased. In this section, we implement the same estimations from more homogeneous samples. We perform four types of subsamples for which the number of farms is high enough. We select only (i) the farrow-to-finish farms; (ii) the farms with no hired labour; (iii) farms with no on-farm feed; and (iv) larger farms.

(i) farrow-to-finish farms. We first focus on the farrow-to-finish farms. Some summary statistics are reported in Table 6. In our sample, the farrow-to-finish farms are larger than the other farms on average. However, they face similar prices of input and output, except for the piglet price, which is lower for the farrow-to-finish farms (as expected). The estimated coefficients associated with this subsample are given in Appendix C.1. It appears that the marginal costs are lower and, thus, the margins slightly higher than the results obtained with the full sample. Standard calculations show that the estimated value of $\partial MC / \partial Y$ is positive for all observations. The farrow-to-finish farms exhibit no scale effect due to input utilization. In addition, we have $\partial^2 v_f / \partial Y^2 = 0$, $\partial^2 v_l / \partial Y^2 > 0$ and $\partial^2 v_p / \partial Y^2 > 0$ (see Appendix C.1) so that the farrow-to-finish farms use relatively more labour and piglets when hog production increases. Again estimated marginal costs and feed prices decrease with output size. As for the full sample, the wedge between MC and MC^e is approximately 2.2 € or 7890 € per year and per farm. Note that the estimates lead to results that are in

accordance with regularity conditions.

Table 6 about here

(ii) Farms with no on-farm feed. The results concerning the farms with no on-farm feed are reported in Table 7, and the estimates are given in Appendix C.2. It appears these farms are smaller than the full sample. The cost economies associated with output size are similar to the full sample. The marginal cost appears to be slightly higher while the margin is slightly lower than the other farms. We have $\partial^2 v_f / \partial Y^2 = 0$, $\partial^2 v_l / \partial Y^2 = 0$ and $\partial^2 v_p / \partial Y^2 > 0$ (see Appendix C.2) and, by inspection, the estimated value of $\partial MC / \partial Y$ is positive for all farms with no on-farm feed. Thus, we obtain similar conclusions with this subsample and the full sample concerning the nature of cost economies.

Table 7 about here

(iii) Farms with no hired labour. With a subsample excluding farms with hired labour, the results change significantly (see Table 8 and Appendix C.3). The average output supply is much lower for farms with no hired labour on average. The cost economies seem to be higher. In addition, the farms with no hired labour have lower marginal costs and higher margins. Our estimations also reveal that $\partial^2 v_f / \partial Y^2 < 0$, $\partial^2 v_l / \partial Y^2 > 0$, and $\partial^2 v_p / \partial Y^2 > 0$, so that the estimated value of $\partial MC / \partial Y$ is negative on average. The farms with no hired labour seem to exhibit scale economies associated with technology, mainly through feed utilization. The farms with no hired labour enjoy lower marginal costs and higher margins due to both scale economies and lower feed prices. The elasticity $\varepsilon_{w_f Y}$ is approximately –0.032, which is slightly higher than for the full sample. The farms with no hired labour seem to be able to reach a lower feed price with respect to their scale operation.

Table 8 about here

(iv) Larger farms. Finally, we focus only on larger farms (superior to the median output). A majority of these farms are farrow-to-finish farms and farms with hired labour.

The results are reported in Table 9 and Appendix C.4. It appears that the average cost is lower for this subsample and that the estimated marginal costs are almost the same as the marginal costs for the full sample. However, the cost economies are similar to the results obtained from the full sample. In addition, our result on the absence of scale economies due to technology holds with this subsample. From Appendix C.4, we have $\partial^2 v_f / \partial Y^2$ and $\partial^2 v_l / \partial Y^2$, which are non significant, while $\partial^2 v_p / \partial Y^2$ is significantly positive. As a result, we have $\partial MC / \partial Y > 0$ at every data point. In addition, from Appendix C.4, it appears the marginal impact of output size on feed price is significantly negative ($\partial w_f / \partial Y < 0$). However, when the margin is lower for the larger farms, it appears that the profits and average profits are higher (see Table 9).

Table 9 about here

To summarize, regardless of the subsample, the unit price of feed decreases with the leel of hog production. It also appears that a larger scale of operation does not induce a fall in the relative use of labour. The only source of scale economies in hog production seems to be related to feed input utilization. More specifically, only the farms with no hired labour seem to exhibit technological scale economies through a better use of feed. Hence, feed plays a significant role in cost economies in the hog sector. In addition, most pig farms face decreasing average costs and increasing marginal costs, meaning that they are close to their minimum average costs.

5. Conclusion

Our study provides a better understanding of the nature and magnitude of cost economies at the hog farm level based on a system of equations including a feed price equation, input demands and output supply. Our hypothesis is that cost economies are not only related to the technology and the relative use of input, but also to the market mechanism in the sense, that unit input prices decreases with the level of production. Indeed, for a given technology, farms may lower their average costs by increasing output in two ways. First, the unit cost can fall as the scale of production increases, given factor prices. Second, by increasing the scale of production, the farmer may obtain a lower input price. Indeed, the unit input prices paid by farmers may differ significantly between them due to the transaction costs or bargaining power associated with the output size. For example, purchasing a larger quantity of feed may reduce transaction costs incurred by the feed supplier (because of lower unit transport costs or a lower number of customers) and allows the feed producers to exploit scale economies.

Our results suggest that the marginal costs are over-estimated when the endogeneity of feed prices is not controlled for. Our study also provides new findings on the nature and magnitude of cost economies at the hog farm level. We have shown that the cost economies associated with output size are due to lower feed prices and not to a fall in the relative use of inputs. However, from a certain threshold of output size, the marginal cost and the marginal profit become non-decreasing and non-increasing, respectively. Furthermore, the farms with no hired labour exhibit scale economies due to their technology and reach higher marginal operating profits than the other types of farms.

We hope that our contribution will motivate further research on economies of size in different livestock sectors as well as in crop sectors where the prices of seed or fertilizer may also be negotiated by farmers. The main challenge lies in the structural estimation of the bargaining power of farmers according to their size.

References

Allen, D., and D. Lueck. 2001. *The Nature of the Farm: Contracts, Risk, and Organization in Agriculture*. Cambridge, MA: The MIT Press.

Alvarez, A., and C. Arias. 2003. "Diseconomies of Size with Fixed Managerial Ability." *American Journal of Agricultural Economics* 85(1):134–142.

Azzam, A., and C. Skinner. 2007. "Vertical economies and the structure of US hog farm." *Canadian journal of agricultural Economics* 55: 349-364.

Beard, R., G. Ford, and D. Kaserman. 2007. "The competitive effects of quantity discounts." *The Antitrust Bulletin* 52, 591-602.

Calzolari, G., and V. Denicolo. 2011. "On the anti-competitive effects of quantity discounts". International Journal of Industrial Organization 29, 337-341.

Chavas, J.P. 2001. "Structural change in agricultural production: economics, technology and policy." In B. Gardner, and G. Rausser, eds. *Handbook in Agricultural Economics. Vol. 1*. Amsterdam: Elsevier Science, pp. 263–285.

Christensen, L. R., D. W. Jorgenson, and L. J. Lau.1973. "Transcendental Logarithmic Production Frontiers." *Review of Economics and Statistics* 55(1): 28-45.

Debertin, D.L. 1986. *Agricultural Production Economics*. New York: Macmillan Publishing Co.

Draganska, M., D. Klapper, and S.B. Villas-Boas. 2010. "A larger slice or a larger pie? An empirical investigation of bargaining power in the distribution channel." *Marketing Science* 29(1):57–74.

Fernandez-Cornejo, J., C. M. Gempesaw II, J. G. Elterich and S. E. Stefanou. 1992. "Dynamic Measures of Scope and Scale Economies: An Application to German Agriculture." *American Journal of Agricultural Economics* 74(2): 329-42.

Gaigné, C., J. Le Gallo, S. Larue, and B. Schmitt. 2012. "Does regulation of manure land application work against agglomeration economies? Theory and evidence from the French hog sector." *American Journal of Agricultural Economics* 94(1):116–132.

Key, N. 2005. "How much do farmers value their independence?" *Agricultural Economics* 33(1): 117-126.

Key, N., W. McBride, and R. Mosheim. 2008. "Decomposition of Total Factor Productivity Change in the U.S. Hog Industry." *Journal of Agricultural and Applied Economics* 40(1):137-149.

Kumbhakar, S.C. 1993. "Short-Run Returns to Scale, Farm-Size, and Economic Efficiency." *Review of Economics and Statistics* 75(2):336-341.

MacDonald, J.M., and W.D. McBride. 2009. *The Transformation of U.S. Livestock Agriculture: Scale, Efficiency and Risks*. Washington DC: U.S. Department of Agriculture, Economic Research Service. EIB-43, January.

MacDonald, J.M., E. O'Donoghue, and R.A. Hoppe. 2010. "Reshaping Global Agricultural Production: Geography, Farm Structure, and Finances." Paper presented at a symposium sponsored by the Federal Reserve Bank of Kansas City, 8-9 June.

Morrison, C. 1988. "Quasi-fixed Inputs in U.S. and Japanese Manufacturing: a Generalized Leontief Restricted Cost Function Approach." *Review of Economics and Statistics* 70(2): 275-287.

Morrison Paul, C.J. 2001a. "Cost Economies and Market Power: The Case of the U.S. Meat Packing Industry." *Review of Economics and Statistics* 83(3):531-540.

Morrison Paul, C.J. 2001b. "Market and Cost Structure in the U.S. Beef Packing Industry: A Plant-Level Analysis." *American Journal of Agricultural Economics* 83(1):64-76.

Moschini, G. 1988. "The Cost Structure of Ontario Dairy Farms: A Microeconomic Analysis." *Canadian Journal of Agricultural Economics* 36(2):187–206.

Mosheim, R., and C.A. Knox Lovell. 2009. "Scale Economies and Inefficiency of U.S. Dairy Farms." *American Journal of Agricultural Economics* 91:777–794.

Nehring, R., J. Gillespie, C. Sandretto, and C. Hallahan. 2009. "Small U.S. Dairy Farms: Can They Compete?" *Agricultural Economics* 40(Issue Supplement s1): 817-25.

Rasmussen, S. 2010. "Scale Efficiency in Danish Agriculture: An Input Distance-Function Approach." *European Review of Agricultural Economics* 37(3): 335-67.

Roguet, C., and M. Rieu. 2011. "Les groupements de producteurs de porcs en France : une organisation originale." Paper presented at 11ème Journée Productions Porcines et Avicoles

Tauer, L.W., and A.K. Mishra. 2006. "Can the Small Dairy Farm Remain Competitive in U.S. Agriculture?" *Food Policy* 31(5):458–68.

Appendix A

A.1. Input price and output size.

Table A.1. Input price and output size (Y) [(a)]

	Feed Price	**Labor price**	**Piglet price**
Constant	166.7*** (73.3)	15.3*** (26.6)	10.09*** (8.4)
Y	-0.0035*** (-5.3)	0.0003* (1.7)	0.0003 (0.8)
Y^2	1.32×10^{-7}** (2.4)	-1.98×10^{-8} (-1.4)	-2.04×10^{-8} (-0.71)
R2	*0.43*	*0.11*	*0.81*

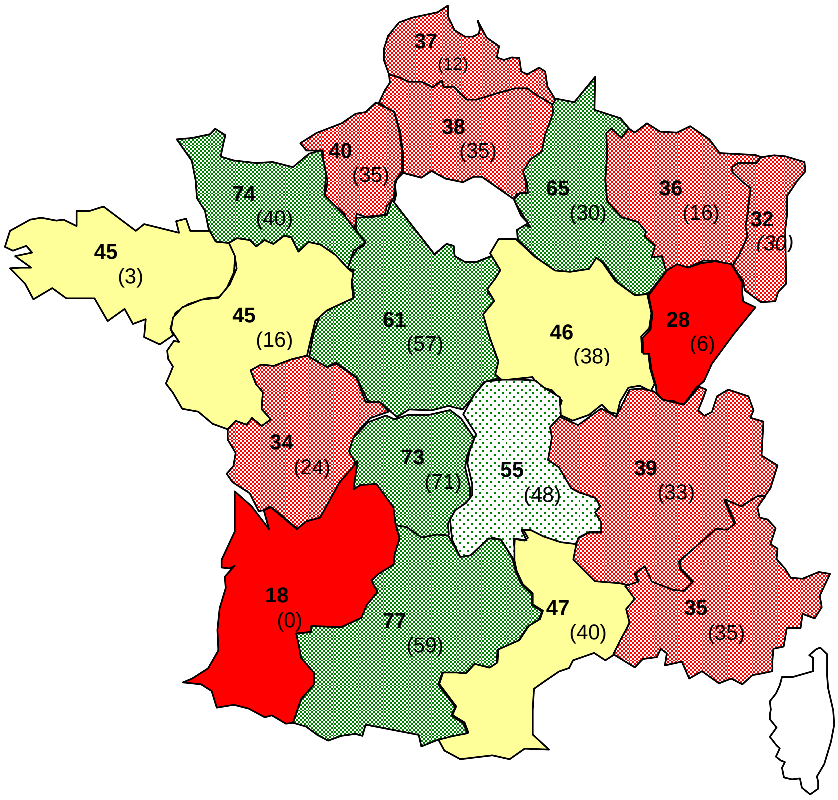
All farms (772 obs) Note: t-statistics are in parentheses. The significance thresholds are respectively 1%(***), 5%(**) and 10%(*).
(a) We use the same control variables as in the system regression, we do not report them but they are available upon request.

A.2 Parameter estimates for all farms (772 obs)

	Estimate	**t-statistics**		**Estimate**	**t-statistics**
$\alpha_{F,F}$	-141.3***	(-6.906)	$\alpha_{P,P}$	-277.4***	(-2.964)
$\alpha_{F,L}$	151.5***	(6.758)	$\alpha_{P,F}$	6.287	(0.693)
$\alpha_{F,P}$	6.287	(0.693)	$\alpha_{P,L}$	52.75	(0.802)
β_F	0.0463***	(33.25)	β_P	0.847***	(27.63)
γ_F	2.30e-07	(0.965)	γ_P	3.93e-05***	(9.142)
$\delta_{F,K}$	0.0123	(0.501)	$\delta_{P,K}$	0.490**	(2.527)
$\delta_{F,S}$	0.128***	(3.652)	$\delta_{P,S}$	6.540***	(8.839)
$\eta_{F,K}$	2.11e-06	(0.738)	$\eta_{P,K}$	-0.000332***	(-6.687)
$\eta_{F,S}$	8.22e-06	(1.016)	$\eta_{P,S}$	-0.00176***	(-16.54)
$\rho_{F,K,K}$	-1.28e-05	(-0.386)	$\rho_{P,K,K}$	0.00117***	(4.037)
$\rho_{F,S,S}$	-0.000189*	(-1.713)	$\rho_{P,S,S}$	0.0214***	(15.48)
$\rho_{F,K,S}$	-7.69e-05	(-0.940)	$\rho_{P,K,S}$	0.00122	(1.623)
$\alpha_{L,L}$	-1,284***	(-5.443)	σ_0	1,963***	(29.55)
$\alpha_{L,F}$	151.5***	(6.758)	σ_1	-0.0264***	(-5.639)
$\alpha_{L,P}$	52.75	(0.802)	σ_2	7.66e-07**	(2.121)
β_L	0.346***	(6.331)			
γ_L	8.88e-06	(0.960)			
$\delta_{L,K}$	-0.529	(-1.109)			
$\delta_{L,S}$	10.33***	(10.07)			
$\eta_{L,K}$	-0.000290**	(-2.445)			
$\eta_{L,S}$	3.59e-05	(0.146)			
$\rho_{L,K,K}$	0.00225***	(3.165)			
$\rho_{L,S,S}$	0.00154	(0.536)			
$\rho_{L,K,S}$	-0.00440**	(-2.422)			

Note: The specification includes control variables: the type of hog farms (4 categories), the on-farm feed production (3 categories), hired labour, regions (4 categories), the producer organisations (24 categories), meat quality (2 categories). We do not report the coefficient values for dummy variables, they are available upon request.
The significance thresholds are respectively 1%(***), 5%(**) and 10%(*).

Appendix B. Participation rate of over 49 sows-farms in GTE system in 2006



Participation rate GTE = 47%
(Participation rate GTE & Performance chart = 16 %**)**

Participation rate in GTE

- < 30 %
- 30-40 %
- 41-50 %
- 51-60 %
- > 60 %

Sources : IFIP-GTE
IFIP according to the Farm Structure Survey
SCEES in 2005

Appendix C

C.1 Parameter Estimates for Farrow-to-Finish Farms (581 obs)

	Estimate	t-statistics		Estimate	t-statistics
$\alpha_{F,F}$	-192.9***	(-7.542)	$\alpha_{P,P}$	-289.4***	(-3.109)
$\alpha_{F,L}$	165.9***	(5.904)	$\alpha_{P,F}$	4.599	(0.470)
$\alpha_{F,P}$	4.599	(0.470)	$\alpha_{P,L}$	62.41	(0.825)
β_F	0.0498***	(25.76)	β_P	0.755***	(17.38)
γ_F	-6.40e-07	(-1.449)	γ_P	0.000114***	(11.61)
$\delta_{F,K}$	0.0329	(0.978)	$\delta_{P,K}$	0.265	(1.077)
$\delta_{F,S}$	-0.0422	(-0.602)	$\delta_{P,S}$	8.838***	(9.196)
$\eta_{F,K}$	3.43e-06	(0.861)	$\eta_{P,K}$	-0.000372***	(-4.198)
$\eta_{F,S}$	3.29e-05**	(2.080)	$\eta_{P,S}$	-0.00399***	(-12.62)
$\varrho_{F,K,K}$	0.000254***	(4.524)	$\varrho_{P,K,K}$	0.00169***	(4.041)
$\varrho_{F,S,S}$	0.000204	(1.041)	$\varrho_{P,S,S}$	0.0354***	(13.23)
$\varrho_{F,K,S}$	-0.000861***	(-4.697)	$\varrho_{P,K,S}$	0.00122	(0.530)
$\alpha_{L,L}$	-1,369***	(-4.373)	σ_0	1,917***	(24.49)
$\alpha_{L,F}$	165.9***	(5.904)	σ_1	-0.0207***	(-3.909)
$\alpha_{L,P}$	62.41	(0.825)	σ_2	4.59e-07	(1.183)
β_L	0.389***	(3.798)			
γ_L	7.37e-05***	(2.919)			
$\delta_{L,K}$	-0.370	(-0.550)			
$\delta_{L,S}$	8.599***	(3.611)			
$\eta_{L,K}$	-0.000229	(-0.982)			
$\eta_{L,S}$	-0.00216***	(-2.617)			
$\varrho_{L,K,K}$	0.00511***	(4.458)			
$\varrho_{L,S,S}$	0.0241***	(3.402)			
$\varrho_{L,K,S}$	-0.0136**	(-2.234)			

Note: The specification includes control variables: the type of hog farms (4 categories), the on-farm feed production (3 categories), hired labour, regions (4 categories), the producer organisations (24 categories), meat quality (2 categories). We do not report the coefficient values for dummy variables, they are available upon request.

The significance thresholds are respectively 1%(***), 5%(**) and 10%(*).

C.2 Parameter Estimates for Farms with No On-Farm Feed (494 obs)

	Estimate	t-statistics		Estimate	t-statistics
$\alpha_{F,F}$	-139.2***	(-5.214)	$\alpha_{P,P}$	-215.0**	(-2.181)
$\alpha_{F,L}$	159.4***	(5.769)	$\alpha_{P,F}$	-11.64	(-1.167)
$\alpha_{F,P}$	-11.64	(-1.167)	$\alpha_{P,L}$	107.0	(1.387)
β_F	0.0460***	(25.89)	β_P	0.871***	(24.30)
γ_F	-2.85e-07	(-0.800)	γ_P	5.96e-05***	(8.355)
$\delta_{F,K}$	-0.0326	(-0.982)	$\delta_{P,K}$	0.287	(1.240)
$\delta_{F,S}$	0.241***	(5.211)	$\delta_{P,S}$	7.929***	(9.672)
$\eta_{F,K}$	-1.43e-07	(-0.0432)	$\eta_{P,K}$	-0.000471***	(-8.485)
$\eta_{F,S}$	2.38e-05*	(1.809)	$\eta_{P,S}$	-0.00248***	(-12.02)
$\varrho_{F,K,K}$	2.57e-05	(0.648)	$\varrho_{P,K,K}$	0.00123***	(3.904)
$\varrho_{F,S,S}$	-0.000947***	(-5.224)	$\varrho_{P,S,S}$	0.0229***	(9.806)
$\varrho_{F,K,S}$	0.000190*	(1.752)	$\varrho_{P,K,S}$	0.00524***	(5.769)
$\alpha_{L,L}$	-1,552***	(-5.218)	σ_0	2,040***	(26.65)
$\alpha_{L,F}$	159.4***	(5.769)	σ_1	-0.0296***	(-4.088)
$\alpha_{L,P}$	107.0	(1.387)	σ_2	1.69e-06**	(2.278)
β_L	0.346***	(4.682)			
γ_L	1.58e-05	(0.891)			
$\delta_{L,K}$	-0.867	(-1.414)			
$\delta_{L,S}$	13.00***	(10.34)			
$\eta_{L,K}$	-0.000491***	(-3.441)			
$\eta_{L,S}$	0.000181	(0.343)			
$\varrho_{L,K,K}$	0.00299***	(3.579)			
$\varrho_{L,S,S}$	-0.0157***	(-2.812)			
$\varrho_{L,K,S}$	0.00230	(0.973)			

Note: The specification includes control variables: the type of hog farms (4 categories), the on-farm feed production (3 categories), hired labour, regions (4 categories), the producer organisations (24 categories), meat quality (2 categories). We do not report the coefficient values for dummy variables, they are available upon request.

The significance thresholds are respectively 1%(***), 5%(**) and 10%(*).

C.3 Parameter Estimates for Farms with No Hired Labour (443 obs)

	Estimate	t-statistics		Estimate	t-statistics
$\alpha_{F,F}$	-64.99***	(-3.487)	$\alpha_{P,P}$	-181.0*	(-1.933)
$\alpha_{F,L}$	106.2***	(3.991)	$\alpha_{P,F}$	-0.907	(-0.0987)
$\alpha_{F,P}$	-0.907	(-0.0987)	(-0.0987)	-9.664	(-0.125)
β_F	0.0442***	(23.97)	β_P	0.938***	(22.82)
γ_F	-7.91e-07*	(-1.939)	γ_P	2.27e-05***	(2.731)
$\delta_{F,K}$	0.0194	(0.798)	$\delta_{P,K}$	0.318	(1.625)
$\delta_{F,S}$	0.102***	(2.589)	$\delta_{P,S}$	6.576***	(6.420)
$\eta_{F,K}$	3.24e-06	(0.702)	$\eta_{P,K}$	-3.96e-05	(-0.463)
$\eta_{F,S}$	2.89e-05*	(1.752)	$\eta_{P,S}$	-0.00220***	(-9.052)
$\varrho_{F,K,K}$	-6.62e-05*	(-1.783)	$\varrho_{P,K,K}$	-0.000327	(-0.787)
$\varrho_{F,S,S}$	2.01e-05	(0.0678)	$\varrho_{P,S,S}$	0.0308***	(6.880)
$\varrho_{F,K,S}$	3.77e-05	(0.299)	$\varrho_{P,K,S}$	-0.000779	(-0.763)
$\alpha_{L,L}$	-517.6*	(-1.726)	σ_0	2,007***	(24.86)
$\alpha_{L,F}$	106.2***	(3.991)	σ_1	-0.0392***	(-4.511)
$\alpha_{L,P}$	-9.664	(-0.125)	σ_2	1.78e-06**	(2.005)
β_L	0.163*	(1.888)			
γ_L	4.69e-05**	(2.236)			
$\delta_{L,K}$	-0.240	(-0.429)			
$\delta_{L,S}$	11.32***	(8.110)			
$\eta_{L,K}$	-0.000699***	(-2.866)			
$\eta_{L,S}$	0.00206***	(3.205)			
$\varrho_{L,K,K}$	0.00247**	(2.067)			
$\varrho_{L,S,S}$	-0.0457***	(-4.152)			
$\varrho_{L,K,S}$	0.00110	(0.374)			

Note: The specification includes control variables: the type of hog farms (4 categories), the on-farm feed production (3 categories), hired labour, regions (4 categories), the producer organisations (24 categories), meat quality (2 categories). We do not report the coefficient values for dummy variables, they are available upon request.
The significance thresholds are respectively 1%(***), 5%(**) and 10%(*).

C.4 Parameter Estimates for Larger Farms (386 obs)

	Estimate	t-statistics		Estimate	t-statistics
$\alpha_{F,F}$	-304.5***	(-7.994)	$\alpha_{P,P}$	-234.4	(-1.501)
$\alpha_{F,L}$	158.7***	(4.426)	$\alpha_{P,F}$	4.668	(0.331)
$\alpha_{F,P}$	4.668	(0.331)	$\alpha_{P,L}$	84.39	(0.820)
β_F	0.0484***	(21.36)	β_P	0.763***	(13.09)
γ_F	-4.75e-08	(-0.137)	γ_P	4.08e-05***	(5.988)
$\delta_{F,K}$	0.0389	(1.002)	$\delta_{P,K}$	0.516*	(1.676)
$\delta_{F,S}$	0.159***	(2.652)	$\delta_{P,S}$	7.610***	(5.562)
$\eta_{F,K}$	4.72e-06	(1.207)	$\eta_{P,K}$	-0.000267***	(-3.339)
$\eta_{F,S}$	1.52e-05	(1.400)	$\eta_{P,S}$	-0.00163***	(-11.04)
$\varrho_{F,K,K}$	-4.36e-05	(-0.941)	$\varrho_{P,K,K}$	0.000888**	(2.093)
$\varrho_{F,S,S}$	-0.000240*	(-1.716)	$\varrho_{P,S,S}$	0.0187***	(8.971)
$\varrho_{F,K,S}$	-0.000202*	(-1.889)	$\varrho_{P,K,S}$	0.000722	(0.696)
$\alpha_{L,L}$	-1,837***	(-4.699)	σ_0	2,173***	(23.59)
$\alpha_{L,F}$	158.7***	(4.426)	σ_1	-0.0134**	(-2.073)
$\alpha_{L,P}$	84.39	(0.820)	σ_2	1.53e-07	(0.348)
β_L	0.452***	(4.848)			
γ_L	7.84e-06	(0.549)			
$\delta_{L,K}$	0.454	(0.603)			
$\delta_{L,S}$	9.800***	(5.968)			
$\eta_{L,K}$	-0.000535***	(-2.879)			
$\eta_{L,S}$	0.000107	(0.314)			
$\varrho_{L,K,K}$	0.00234**	(2.288)			
$\varrho_{L,S,S}$	0.000880	(0.245)			
$\varrho_{L,K,S}$	-0.00354	(-1.425)			

Note: The specification includes control variables: the type of hog farms (4 categories), the on-farm feed production (3 categories), hired labour, regions (4 categories), the producer organisations (24 categories), meat quality (2 categories). We do not report the coefficient values for dummy variables, they are available upon request.

The significance thresholds are respectively 1%(***), 5%(**) and 10%(*).

Table 1. Summary statistics – all farms (772 obs.)

	Mean	Std. Dev.	1st Quartile	Median	3rd Quartile
Feed price (€/ton)	169.19	16.34	159.46	169.00	178.79
Labour price (€/hours)	16.12	3.30	14.35	16.14	17.10
Piglet price (€/head)	18.30	14.97	8.62	9.98	33.02
Output price (€/head)	118.35	13.46	111.73	119.94	126.01
Output (head)	2,426	1,868	1,214	1,913	2,853

Source: IFIP – GTE-TB databases

Table 2. Summary statistics – all farms (772 obs.)

	Mean	Std. Dev.	1st Quartile	Median	3rd Quartile
Variable cost(a) (€)	211,190	158,472	113,310	163,048	246,880
Total cost (€)	276,506	196,965	149,553	220,244	330,199
Average cost (€)	120.70	34.61	105.11	113.98	128.43
Total profit (€)	8,518	69,404	-16,548	7,503	36,775
Average profit (€)	-2.35	37	-10.19	4.80	15.42

(a) variable cost corresponds to the sum of variable input costs (G)

Source: IFIP – GTE-TB databases

Table 3. Elasticities of input demand – all farms (772 obs.)

	Elasticities of input demand	
	output supply	**input price**
	$\partial v_i/\partial Y_i . Y_i/v_i$	$\partial v_i/\partial w_i . w_i/v_i$
Feed	1.13 (0.43)	-0.11 (0.09)
Labour	0.48 (0.34)	-0.58 (0.51)
Piglet	0.87 (0.21)	-0.004 (0.002)

Note: Standard deviation in parentheses

Table 4. Cost elasticities, marginal costs and margins – all farms (772 obs.)

	Mean	Std. Dev.	1st Quartile	Median	3rd Quartile
	without adjustment in unit feed price to a change in production				
$\varepsilon_{C,Y}$	0.89	0.19	0.78	0.89	1.01
Marginal cost (MC)	103.7	15.4	92.8	98.6	114.7
Margin	14.7	18.4	2.0	17.3	28.1
	with adjustment in unit feed price to a change in production				
$\varepsilon_{C,Y}+\varepsilon_{wf,Y}. w_f v_f/C$	0.87	0.19	0.76	0.87	0.99
$MC^e=MC+v_f.\partial w_f/\partial Y$	101.2	16.0	90.1	96.1	112.8
$MC - MC^e$	2.41	1.52	1.27	2.04	3.15

Table 5. Short-run cost elasticities without an endogenous feed price, marginal costs and margins by region – all farms (772 obs.)

	Mean	Std. Dev.	1st Quartile	Median	3rd Quartile
			Bretagne		
$\varepsilon_{C,Y}$	0.88	0.15	0.78	0.86	0.96
Marginal cost	97.2	10.8	90.0	93.7	100.1
Margin	19.6	15.2	8.2	23.0	31.9
			Pays-de-Loire		
$\varepsilon_{C,Y}$	0.87	0.17	0.79	0.88	0.96
Marginal cost	100.2	13.6	91.3	94.8	103.5
Margin	17.0	19.1	2.9	24.4	29.8
			Normandie		
$\varepsilon_{C,Y}$	0.92	0.24	0.77	0.91	1.07
Marginal cost	102.6	11.5	95.2	100.0	109.9
Margin	11.3	16.8	-2.4	13.4	20.8

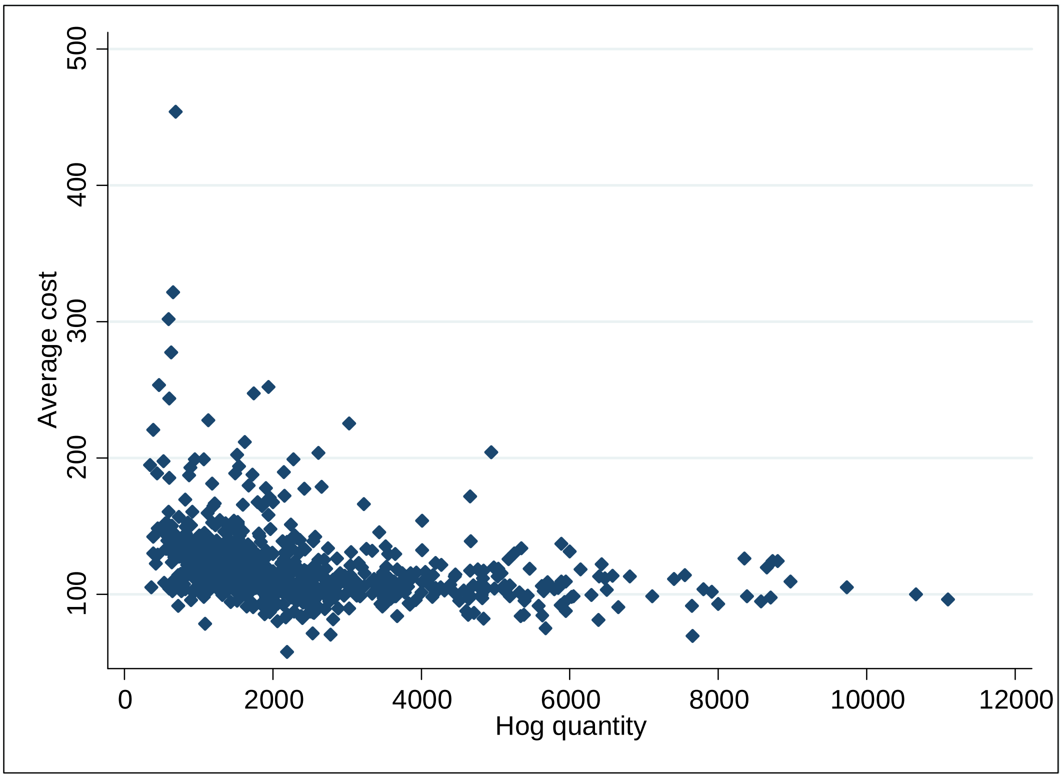


Figure 1. Average cost and output size

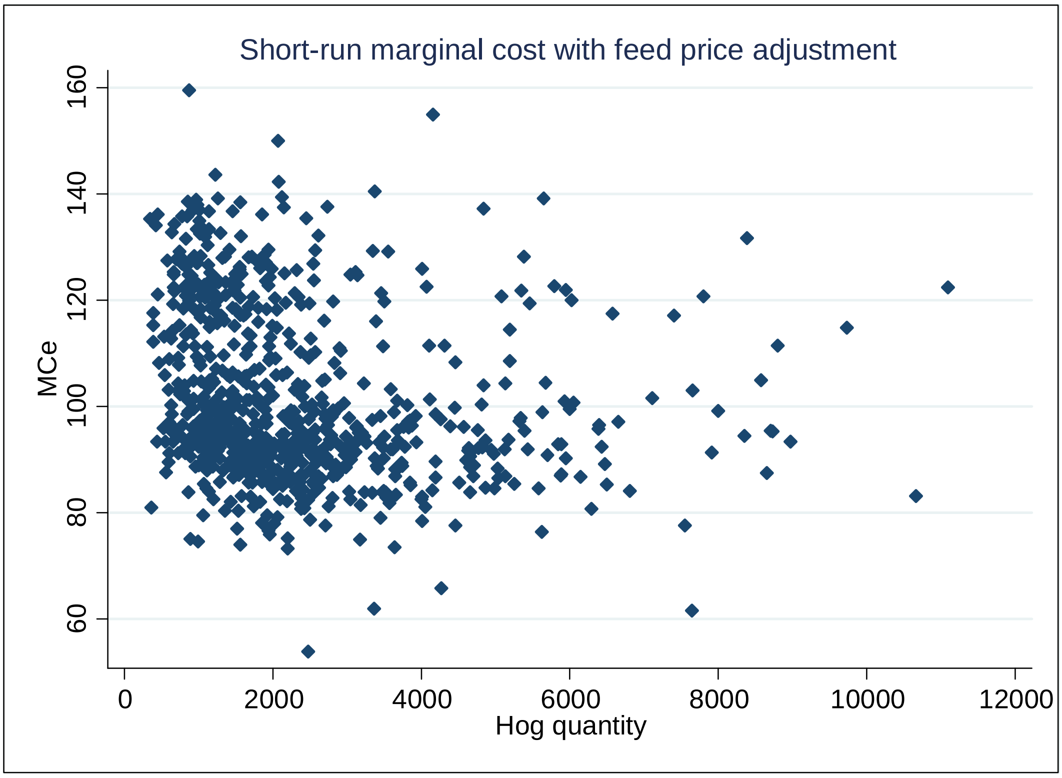


Figure 2. Marginal cost and output size

Table 6. Cost elasticities, marginal mosts and margins for farrow-to-finish farms (581 obs)

	Mean	Std. Dev.	1st Quartile	Median	3rd Quartile
Output	2,642	1,945	1,421	2,152	3,156
Average cost	120.47	38.06	103.15	111.90	128.50
Profit	8,711	76,131	-20,791	9,279	44,864
Average profit	-3.25	40.36	-11.56	4.72	16.44
	without adjustment in unit feed price to a change in production				
$\varepsilon_{C,Y}$	0.89	0.19	0.79	0.90	0.99
Marginal cost	102.2	10.3	96.4	101.1	106.7
Margin	15.0	15.8	6.7	16.3	25.1
	with adjustment in unit feed price to a change in production				
$\varepsilon_{C,Y}$	0.87	0.19	0.78	0.88	0.97
Marginal cost	100.0	10.6	94.0	98.9	104.5
Margin	17.2	15.9	8.6	18.5	27.2

Table 7. Cost elasticities, marginal costs and margins for no on-farm feed farms (494 obs)

	Mean	Std. Dev.	1st Quartile	Median	3rd Quartile
Output	2,197	1,637	1,137	1,739	2,613
Average cost	122.8	37.71	106.8	115.8	129.4
Profit	2,526	67,646	-19,154	4,317	27,028
Average profit	-4.84	40.15	-12.26	2.92	13.33
	without adjustment in unit feed price to a change in production				
$\varepsilon_{C,Y}$	0.89	0.19	0.78	0.88	1.01
Marginal cost	104.6	15.3	93.5	99.2	114.6
Margin	13.3	17.8	0.2	16.4	26.6
	with adjustment in unit feed price to a change in production				
$\varepsilon_{C,Y}$	0.87	0.19	0.77	0.87	1.00
Marginal cost	102.8	15.8	91.3	97.2	113.6
Margin	15.2	18.2	2.1	18.1	28.5

Table 8. Cost elasticities, marginal costs and margins for no hired labour farms (443 obs)

	Mean	Std. Dev.	1st Quartile	Median	3rd Quartile
Output	1,793	1,150	1,066	1,545	2,244
Average cost	120.3	26.26	105.9	115.8	129.1
Profit	9,271	47,180	-14,610	5,454	28,075
Average profit	-0.88	29.05	-10.22	4.24	14.76
	without adjustment in unit feed price to a change in production				
$\varepsilon_{C,Y}$	0.87	0.16	0.78	0.87	0.98
Marginal cost	101.7	14.5	90.2	97.6	113.3
Margin	17.8	17.5	4.9	19.9	29.7
	with adjustment in unit feed price to a change in production				
$\varepsilon_{C,Y}$	0.85	0.16	0.75	0.84	0.96
Marginal cost	99.2	15.2	87.5	95.0	111.2
Margin	20.3	18.1	7.0	22.1	32.4

Table 9. Cost elasticities, marginal costs and margins for larger farms (386 obs)

	Mean	Std. Dev.	1st Quartile	Median	3rd Quartile
Output	3,619	1,996	2,356	2,853	4,256
Average cost	111.12	21.01	99.86	107.87	115.99
Profit	25,993	84,434	-9,904	33,041	66,521
Average profit	5.71	24.24	-3.74	11.06	20.40
	without adjustment in unit feed price to a change in production				
$\varepsilon_{C,Y}$	0.96	0.18	0.85	0.94	1.06
Marginal cost	103.5	13.3	95.1	100.8	108.6
Margin	13.3	17.2	2.4	15.6	25.3
	with adjustment in unit feed price to a change in production				
$\varepsilon_{C,Y}$	0.94	0.18	0.83	0.92	1.04
Marginal cost	101.4	13.5	92.9	98.2	106.7
Margin	15.4	17.4	4.2	18.3	27.2