Investigating Market Power in the Belgian Pork Production Chain

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Abstract

The Belgian pork production has been confronted with stagnating prices for decades. It remains unclear whether excessive market power from slaughterhouses or meat retailers plays a role. Market power studies can reveal some of the market dynamics in this setting, but this type of research has not yet been applied to the Belgian pork market. This paper investigates oligopolies and oligopsonies in the pork production sector. A new model is built to focus on market power dynamics in the market for live pigs. This model distinguishes horizontal and vertical market power parameters both for pig farmers and for slaughterhouses. The results follow from an empirical application using unique slaughterhouses data for the period 2001–2015. The results indicate that the farmers benefit from a significant power advantage in the live pig market. The final market price of live pigs approaches more closely to the requested price by the farmers. On the other hand, the measured vertical market power also suggests that a pig farmer does not receive the (modest) full-wage-based salary. The market power of the slaughterhouses is limited. Market power as a result of collusion, that is, horizontal market power, is present but is not strong. There are, however, significant differences between the slaughterhouses in terms of mark-up on the input prices. These differences reflect differences in company strategy, and this diversity further reduces the possibility to create sector-wide collusive behaviour.

1. Introduction

Prices for meat products have been stagnating for years in Belgium. Both the animal raising farms as well as the slaughterhouse sector show a low level of profitability. Already at the start of the century, studies showed that poverty was widely present among family farms in Belgium, and many did not earn more than minimum wage (Van Hecke, 2001). This situation has not improved in recent years, particularly for farms specialising in animal products. Official reports have been commissioned to review average farm profitability (Deuninck et al., 2009). Farms specialising in piglet breeding had

negative income from 2006 to 2008 (FOD Economie, 2010). In 2007 and 2008, the negative income was even present before subtracting the annual farm's household income. Farms specialising in pig fattening presented a slightly better profitability, and showed a small positive benefit during this period. However, profits remained under pressure from increasing fodder prices and decreasing prices for live pigs. A follow-up report showed that this situation again deteriorated during the years 2010–2012 (Vrints and Deuninck, 2013).

Authorities are concerned that price transmission in the meat column in Belgium is not fully competitive. The National Price Observatory was asked to conduct several studies on the price and cost structure of the beef and pork production column (FOD Economie, 2009, 2010). These studies were motivated by the difficult situation of the animal husbandry sectors. The reports highlighted the problems of price formation, showing that the obtained prices could not cover the production costs for several actors in the supply chain. The situation also led to frequent consultations between farmers' syndicates and representatives of the slaughterhouse and the retail meat sector. In addition, policy-supported initiatives developed roadmaps and action plans towards a transparent, differentiated, and collaborating pig value chain.

Starting from this (and subsequent) evidence, this paper examines the interesting and long-standing issue of analysing the market power exerted in a supply chain using multiple stages of the chain itself. The slaughterhouses are central players in this supply chain as the primary purchasers of live animals from farmers and the main suppliers of carcasses to the Belgian retail sector and the food industry. The oligopsonic threat in this sector is a potential issue due to agricultural production that may involve a lack of coordinated production control among pig farmers (the supply side) and a highly concentrated market of pig slaughterhouses due to significant scale economies (the demand side).

This research starts with the empirical verification of a continued low price level for live pigs. The first part of the model focuses on the dynamics of this price determination following the methodology originated by Azzam (1996). The price setting in the market of live pigs is based on the interaction between the slaughterhouses and the individual farmers who present their animals leading to power balances vertically in the value chain. Our method of retrieving the price setting involves a bargaining power indicator that identifies to what extent these prices are bargained by the farmer or the slaughterhouse. In this paper, the empirical possibility of this model specifies this bargaining parameter in the context of whether there is a gap between a wage that covers all farming costs and a wage that would be fully bargained by the slaughterhouse. The second part of the model entails an extension of a microeconomic version of Hall's (1988) framework for estimating markups that take into account frictions in the intermediate input factor market. The model is based on a simplified assumption that the slaughterhouse has vertical market power over pig farmers; however, this yields a method which may be useful to analyse bilateral oligopoly in many situations.

Besides the main contribution of assessing market power in the supply chain of the pork sector, the paper provides a way to model output and input market frictions without the need to estimate marginal costs, and also considers to what extent our estimates are sensitive to different model specifications. Most popular approaches in empirical industrial organisations rely on total costs data for calculating market power. The model is different from the standard models using production function approaches, which involves either specific assumptions on the functional behavior between inputs and outputs and/or

sophisticated econometric techniques to identify the structural parameters of a model (see Amoroso et al., 2015, for a recent overview). In particular, our identification strategy follows a standard assumption in the conduct parameter models that marginal costs are constant with respect to quantity, but may be dependent on other external shift parameters. Conditional on the interest of the analysis, identification of market power can be further disentangled into a conjectural variation and the elasticity of demand.

As already mentioned, Belgium provides an interesting case. It is a small country with a large and highly specialised meat industry, resulting in a high regional concentration of livestock and a large, diverse slaughterhouse sector. However, this type of analysis can be equally informative for several European regions. Indeed, this situation is also found in other European regions such as in Germany (Bayern, Niedersachsen, Nordrhein-Westfalen, Schleswig-Holstein), Denmark, Ireland, eastern Spain, France (Normandy, Bretagne), the west and south of the Netherlands, and the central region of Poland. In this case, Belgium's particular advantage is its limited size, making it possible to complement regional data with data that is available on a national level, thus leading to more detailed results.

The remainder of the text is structured as follows. Section 2 highlights the background of the pork sector in Belgium by looking at some market structural variables. Section 3 describes the construction of the model that reflects the specific market characteristics for live animals and meat products in Belgium. Section 4 provides results and an interpretation of the variables. Section 5 concludes.

2. Overview of the pig market sector in Belgium

The first group of actors in this value chain are the pig farmers. As illustrated in Table 1, the number of pig farmers has been decreasing steadily since 2000. The total stock of pigs has reduced as well, but only to a limited extent. This is explained by the increasing scale of pig husbandry in Belgium. The average pig farm has almost doubled its size, from 720 pigs per farm in 2000, to 1346 pigs in 2015. This continued consolidation reduced the total number of pig farmers. But the large number of farmers is in itself not an indication of market concentration. The farmers are well organised. There are two farmers unions with considerable operational and political power, and a specific union for pig producers is equally active in improving the working conditions of this sector.

In Belgium, all pigs are slaughtered in registered slaughterhouses. The role of slaughterhouses is pivotal in the meat supply chain. Unlike in other countries (Hayenga et al., 2000; Schulze et al., 2006), strong vertical integration in Belgium is uncommon. The slaughterhouse sector in Belgium is highly diverse and has a large number of independent entities. Over the years, this sector has seen also a strong trend to consolidation. Whereas more than 200 slaughterhouses were active around 1995, about 90 large active sites remained in 2011. Table 2 reports the numbers of active slaughterhouses for pigs, based on official data from the Federal Agency for the Safety of the Food Chain (FAVV). The smallest entities, with fewer than 10 animals per year, were excluded because they are related to artisanal butchers and local actors that rely on a personal supply chain. Also note that a number of mixed slaughterhouses are active in the production of both beef and pork. These mixed slaughterhouses are historically related to communal slaughterhouses in rural areas. On the other hand, large industrial slaughterhouses have specialised in pork production. The largest share of the market is occupied by a limited number of these specialised pig slaughterhouses. The Herfindahl-Hirschman (HHI) index (Hirschman, 1964) indicates a

slow, gradual consolidation of the pig slaughterhouse sector. Over the years, there has been a gradually increasing market share of the specialised pig slaughterhouses.

Table 4 column 9 reports the average annual input price index for live pigs. We observe an initial high price variability between 2001 and 2002 as the result of the second BSE crisis, which led to a relative high demand of pork. The subsequent period was characterised as a relatively stable price evolution. In the latter years 2010–2013, these prices rose again. The price setting in the market of live pigs is based on the interaction between the slaughterhouses and the individual farmers who present their animals. In the past, this interaction on a one-to-one basis resulted in a high variability of prices among farmers and regions. Certainly, during the last decade, price differences among farmers for live pigs diminished and the price became increasingly levelled across the sector. Three trends contribute to this evolution. First, slaughterhouses now publish weekly their generic purchase prices. Farmers are very well informed of price movements and tendencies. Individual farmers negotiate within a small variation of the published price depending on the quality of their animals. VEVA, the cooperation of Belgian pig farmers, collects the weekly net prices that farmers receive after negotiation. These prices differ little from the published prices and closely follow the average prices throughout the year. Secondly, the slaughterhouses stress that negotiations with farmers are hard. Past investments in larger industrial pig slaughterhouses brought the slaughterhouse sector close to overcapacity. Significant effort is required from the slaughterhouses to obtain a sufficient number of live animals in order to maintain the slaughterhouse operational at its full capacity. Therefore, competition for live animals among slaughterhouses is fierce. Finally, the interaction with markets in neighbouring countries is also an important influence for price setting. For negotiations of the live pig prices, the price levels of the local market are considered as well as the published purchase prices in Germany (Schleswig-Holstein) and the Netherlands (FOD Economie 2015). There is very little actual export of live animals to these countries, but the sales of pig carcasses happen on an open global market. Most of the produced pork is intended for export. These tendencies are illustrated in Table 3. A minimal net import of live pigs is present in Belgium (except for 2015). On the other hand, the export of carcasses is very important. More than 50% of the total pork production in Belgium was destined for export in 2005, and this part has increased to two thirds of the production in 2015.

3. Model approach

The overview of the different actors and tendencies allows us to delimit the factors of the market power model. Two different markets are included: (i) the market of live pigs, and (ii) the market of pig carcasses. The main focus of this research lies on the dynamics in the live pig market for the exchange of live animals between pig farmers and pig slaughterhouses. Both parties have opportunities to improve their respective market position, so the model should incorporate the measurement of bilateral market power.

The pig farmers coordinate to improve their market position. In general, this can lead to collusive behaviour in the coordination of two strategic variables – price and quantity. The pig farmers'

coordination involves price transparency and information, so the model has to account for market power in that sense. However, with the large number of pig farmers involved – over 4.000 farms – collusion by coordination of production quantity is highly unlikely. With over 4.000 farms, a coordinated control of the quantity of produced live pigs would leave a too-large incentive for free riders. The evolution of the production levels also contradicts this assumption. The market position of pig farms would be enhanced if the collusion reduced the total quantity of live pigs. During the last decade, however, pig farms have invested heavily in increasing their individual production capacities and maintained large production levels despite adverse market conditions.

The pig slaughterhouses are in a different position. This group can behave strategically to improve its position on the live pig market. As the specialised pig slaughterhouses have the largest share of the market, there is a potential for strategic behaviour to control both quantity and price. The model must account for both dynamics.

The second market, the market of pig carcasses, is a fully global market. Whereas live pigs can only be transported for limited distances before reaching the processing facility, the processed intermediate products can readily be sold in the international market, and the sales are therefore directly influenced by the prices in the international markets. At this scale, the specialised pig slaughterhouses are assumed to be price takers in their output market.

3.1. Structural market models

The market power estimation follows a structural market analysis approach. There are several approaches to estimate market power, such as conduct-performance models, industrial structure analysis, or dynamic games (Perloff et al., 2007). A specific strand of industrial structure used this approach extensively and has been grouped under the name “new empirical industrial organization“ (NEIO) (Bresnahan, 1989). The NEIO approach frequently measures market power by estimating conjectural variations (Iwata, 1974). The conjectural variation is based on one strategic output of a firm (most often price or quantity) and indicates whether firms regulate their strategic output as a consequence of their competitors’ change in output. When non-negligible interaction is measured, the conjectural variation reveals different types of non-competitive market behaviour, such as collusion or price arrangements between competitors (Appelbaum, 1982). The conjectural variation may also be directly linked to a price wedge and to standard price mark-ups, such as the Lerner index. Depending on the range of conjectural variations, different types of collusion or market leadership by a predominant actor may be discovered (Roy et al., 2006). Predicting the most appropriate type of market distortion is not possible. The NEIO approach allows for this freedom and maintains a reasonably simple model structure on the basis of a single parameter per market (Sexton, 2000).

The single-sided use of conjectural variation in only the input or output market has frequently been applied in agricultural markets (Myers et al., 2010) and most regularly in the beef packing industry in the United States (Sheldon and Sperling, 2003). Lloyd et al. (2006) used the market shock created by the crisis sparked by the mad-cow disease in the United Kingdom to investigate market powers in the UK beef market. Applications also looked at mark-ups in Australia (Chung and Griffith, 2009) or the Ukraine (Perekhozhuk et al., 2011) among others. This single-sided analysis was further refined to account for input substitution (Azzam and Pagoulatos, 1990), regional consolidation (Azzam and

Schroeter, 1991), and relations' regional and national indications of oligopsony (Perekhozhuk et al., 2015). Whereas these studies mostly looked at the power structure at the sector level, further detailed analysis could use data at the firm level. Therefore, an increasing number of studies combined the effect of market power and firm efficiency (Delis and Tsionas, 2009; Kutlu and Sickles, 2012, Lopez et al., 2002).

The double-sided investigation of input and output markets, which leads to approximations of oligopolic and oligopsonic behaviours, is equally possible. Schroeter (1988) set up the first application of both mark-ups in output and markdowns in input markets to investigate the evolution of market powers in the US beef packing industry. For instance, other applications showed the evolution of both mark-ups and mark-downs in the US pulp and paper industry (Mei and Sun, 2008). In France, an important study uncovered significant market powers in the retail of dairy and meat products (Gohin and Guyomard, 2000). Yanaura and Xia (2016) look at bilateral market power between US–Japan importers and exporters of agricultural commodities. Additionally, a link between welfare loss and imperfect markets was established (Mérel, 2011). Further elaboration of the models led to methods to quantify imperfect price transmission between different actors in the value chain, in both theory (McCorriston et al., 2001; Weldegebriel, 2004) and in practice (Gonzales et al., 2002).

Because the model is based on the single parameter of conjectural variation, Morrison Paul (2001) called for caution when interpreting the results because other effects that are not related to active market collusion can also influence this single parameter, such as large efficiency differences in the sector or missing inputs. Other criticisms of this approach indicate that the results of these models provide only modest departures from perfect competition and that the figures are difficult to precisely define. However, this notion is also related to the limited availability of precise data to which the early NEIO models were applied (Myers et al., 2010). In each case, the results are useful starting points for more detailed analyses subsequently modelling a specific market configuration.

3.2. The situation of the pig farmers

In this case, the market between farmers and processors needs to account for the possibility of oligopolistic behaviour of farmers as well as oligopsonic behaviour of processors. There is thus a potential for bilateral market powers, where collusive behaviour on the supply side can be compensated by similar behaviour on the demand side. This type of analysis was first proposed by Azzam (1996). This approach has been applied to the Danish pork production chain (Jensen 2009), and to optimising marketing for food retailing (Chung et al., 2014). Kinoshita et al. (2006) have extended this method to be applied over several levels of the Japanese dairy production chain. However, these applications have not yet integrated the role of competition in international markets for food products. An adapted model was therefore constructed for this case.

For the market of live pigs, we must include the balance of market power between farmers and slaughterhouses. In this case, a bilateral oligopoly–oligopsony should be considered, leading to power balances vertically in the value chain. Following Azzam (1996), the final price of farm live pigs p_F is defined by:

$$p_F = \alpha p_F^{Upper} + (1-\alpha) p_F^{Lower} \quad (1)$$

Here, α is the indicator for the vertical market power of the farm cooperatives. p_F is determined as a weighted average between p_F^{Upper} and p_F^{Lower}. p_F^{Upper} is the highest price the farmers could obtain if they were the price setters in this market. This price is determined based on the cost structure of the pig farmers. p_F^{Lower} is the lowest price the pig slaughterhouses could obtain for their input if they were the sole price setters. This price is determined by the production and cost structure of the slaughterhouses.

On the farmers' side, the profit π_i of an individual farm *i* can be expressed as:

$$\pi_i = p_F q_i - C_F(V_i) \tag{2}$$

where p_F is the unit price for the farm product (live pigs), q_i is the produced quantity by farm *i*, and $C_F(V_i)$ is the production cost dependent on a vector of inputs V_i. When the farmers strategically optimise their quantity of production, the first order condition yields the following equation:

$$p_F^{Upper}\left(1 + \frac{ms_{Fi}\eta_{Fi}}{\varepsilon_{SFi}}\right) = MC_F(V_i) \tag{3}$$

$$p_F^{Upper}\mu_{Fi} = MC_F(V_i) \tag{4}$$

where MC_F is the marginal production cost at the farm, ms_{Fi} is the market share of farm *i*, ε_{SFi} is the price elasticity of supply, and η_{Fi} is the conduct parameter. This conduct parameter is originally defined as a conjectural variation (CV). This CV explicitly captures the strategic disposition of the farms to adapt their production quantity to the quantity produced by all other farms, and thus measures collusive behaviour. In the literature, there is an increasing tendency to interpret this as a general market power parameter with range $\left[0, {}^{1}/_{ms_{Fi}}\right]$ (Sexton et al., 2007). When the market parameter is 0, the price equals marginal costs, and the situation reflects perfect competition. At the maximum the price reflects a collusive cooperation as a monopoly. What is most relevant in this context is that the market power indicator μ_{Fi} in equation (4) reflects the effect of horizontal market power, that is, the collusive behaviour between farmers. This is less likely in the case of the pig farmers. It is therefore assumed that μ_{Fi} equals unity for the case of the pig farmers. This assumption is also possible following the definition of the marginal costs estimation.

Identification

The preferred solution is to approximate the different cost functions of the actors directly. Following Sexton et al. (2007) and Kinoshita et al. (2006), we assume linear marginal cost functions for the farms. These marginal costs are influenced by price fluctuations of factor inputs, leading to:

$$MC_F(V_i) = \sum_{i=1}^{4}\sum_{i=1}^{4} c_{Fi}w_{Fi} \tag{5}$$

Here, w_{Fi} are price indexes for $i \in$ (land, capital, labour, feedstock). This approximation can be done based on individual farm-level data from the European Farm Accountancy Data Network (FADN).

Based on equations (1) and (4), $\widehat{p_F^L}$, and thus an estimation for p_F^{Lower} can be constructed. When a continuous distribution of margins is assumed in the upper part of the pork value chain, the evolution of p_F^{Lower}, being the lower negotiation value offered by slaughterhouses, can be approximated by following the pork price index I_p reported by the Belgian Statistics Office. The prices are thus estimated as follows:

$$\widehat{p_F^L} = \beta I_P \tag{6}$$

and equation (1) becomes:

$$p_F = \alpha MC_F(V_i) + (1-\alpha)\beta I_P \tag{7}$$

Equation (4) provides the basis for the price setting. The marginal costs that measures the upper limit of the live pigs, p_F^{Upper}, define the bargaining position of pig farmers. These marginal costs define the negotiation starting point for the pig farmers. Usually, farm income is calculated on the basis of ex post market prices whereby wages are determined endogenously: once the market prices are determined, we can solve for wages. Here, we assume exogenous wages where we include paid and unpaid labour (see Section 4). Unpaid labour is valued according to the average gross hourly salary for artisanal labourers in Belgium. This implies that the requested remuneration is supposed to cover all costs, including financing of land and a full wage based on the artisanal labourer's salaries. In this sense, vertical market power as measured by α with a value less than 1 (100%) implies that a pig farmer does not receive a (modest) full-wage-based salary.

The determined marginal costs allow equation (7) to be estimated.

$$p_F = \alpha MC_F(V_i) + \lambda \mathrm{I}_P + \nu_t \tag{8}$$

The parameters $\hat{\alpha}$ and $\hat{\lambda}$ are used to interpret the relative dominance of farmers versus slaughterhouses in terms of market power. The link between the pork price index and the negotiation objective of the slaughterhouses, $\hat{\beta}$, can be derived from $\hat{\lambda}$.

3.3. The situation of the pig slaughterhouses

The second part is the situation of the processors, or the pig slaughterhouses. In particular, we let each firm $j \in \{1, \dots N\}$ face the following production function:

$$Y_j = A_j \mathrm{F}_j(X_j) \qquad j = 1,2, \dots N \tag{9}$$

where Y_j measures firm j 's gross output, $X_j \equiv (X_{j1t}, X_{j2t}, \ldots, X_{jLt})$ denotes the vector of L nonnegative factor inputs (capital, labor,…), $\mathrm{F}_j(.)$ is the core of the (differentiable) production function, and A_j is the total factor productivity (TFP) measured as the rate of a Hicks-neutral disembodied technology. The logarithmic differentiation of production function (9) yields:

$$\frac{dY_j}{Y_j} = \frac{dA_j}{A_j} + \sum_{l=1}^{L} \frac{X_{jl}}{F_j(.)} \frac{\partial F_j(.)}{\partial X_{jk}} \frac{dX_{jk}}{X_{jk}} \tag{10}$$

with $\frac{dY_j}{Y_{jt}}$ (logarithmic) output growth and $\frac{dA_{jt}}{A_{jt}}$ (logarithmic) TFP growth. It is assumed that each firm j faces an inverse demand function, $p_j(Y, Z)$, which represents the market price as a function of aggregate (industry) output $Y \equiv \sum_{j=1}^{J} Y_j$; that is, by specifying firm j's (output) price as an arbitrary function of aggregate output, we allow for various potential degrees of firm j's market power, and Z as the vector of demand-related variables (here we need to specify, for instance, the world price as well as other market demand-related variables).

Firm j's optimisation problem can be written as:

$$Max_{(Y_j, X_j)} = \left[(p_j(Y, Z)\right] - p_F^{Lower}(Y, Z)) - W_j' X_j \parallel Y_j = A_j \mathrm{F}_j\left(X_j\right)] \tag{11}$$

where $W_j \equiv (V_{j1}, V_{j2}, \ldots, V_{jL})$ is firm j's vector of L_j input prices, and $p_F^{Lower}(Y, Z)$ is the lowest price the pig slaughterhouses could obtain for their input of live pigs if they were the price setters in that market.

Assuming in the first instance that there is imperfect competition in the input market and perfect competition in the output markets (a oligopolistic firm acting as a price setter in its input market and a price taker in its output markets), the first order conditions (FOCs) implied by the solution of (11) yield the following equations for the Lagrange multiplier and the nominal input prices:

$$(p_j(Y, Z) - p_F^{Lower}(Y, Z) - \frac{\partial p_F^{Lower}(Y, Z)}{\partial Y} \frac{\partial Y}{\partial Y_j} Y_j = p_j^*$$

$$\text{and } \left[(p_j(Y, Z) - p_F^{Lower}(Y, Z) - Y_j \frac{\partial p_F^{Lower}(Y,Z)}{\partial Y} \frac{\partial Y}{\partial Y_j}\right] \frac{\partial Y}{\partial X_j} = W_j \tag{12}$$

where, according to Diewert and Fox (2008), the Lagrange multiplier p_j^* is firm j's shadow or marginal price of output under profit maximisation, and market power enables firm j to set each input's marginal product, $\frac{\partial Y_t}{\partial X_j}$, above the respective factor cost. $ms_j = \frac{Y_j}{Y_t}$ is the market share of firm j; $\varepsilon_{jF} \equiv -\frac{\partial Y}{\partial p_F^{Lower}(Y,Z)} \frac{p_F^{Lower}(Y,Z)}{Y}$ is the (absolute value of) elasticity of supply in the input market; $\vartheta = \frac{\partial Y}{\partial Y_j}$ is the

conduct parameter. The solution to the profit maximisation as shown in equation (12) can be rewritten as:

$$p_j^* = p_j - p_F^{Lower}(Y,Z)\frac{\partial p_F^{Lower}(Y,Z)}{\partial Y}\frac{\partial Y}{\partial Y_j}Y_j \tag{13}$$

$$= p_j - p_F^{Lower}(Y,Z)\left[1 - \frac{ms_j}{\varepsilon_{jF}}\,\vartheta_j\right] \tag{14}$$

where the term between square brackets is firm *j*'s *mark-up* in the input market. Note that in the case of perfect competition, $\frac{\partial p_j(Y)}{\partial Y}$ goes to zero, implying that prices are set at marginal cost and inputs are paid their marginal products (with mark-up equal to 1).

An approach for measuring market power is to measure the conduct parameter ϑ_j instead of using the Lerner index (Bresnahan, 1989; Corts, 1999). As in Kutlu and Sickles (2012), the definition of MC follows from equation (14) when inputs are paid their marginal products:

$$MC_j = p_j - p_F^{Lower}(Y,Z)\left[1 - \frac{ms_j}{\varepsilon_{jF}}\,\vartheta_j\right] \tag{15}$$

where $\varepsilon_{jF} \approx \varepsilon_F$ is the elasticity of aggregate input supply.

Identification

Following Kutlu and Sickles (2012), we may rewrite expression (15) as

$$p_j - MC_j = \left[1 - \frac{ms_j}{\varepsilon_{jF}}\,\vartheta_j\right] p_F^{Lower}(Y,Z) \tag{16}$$

$$p_j - MC_j = \mu(ms_j, \vartheta_j, \varepsilon) p_F^{Lower}(Y,Z) + \nu_j \tag{17}$$

where $\mu = 1 - \frac{ms_j}{\varepsilon_{jF}}\,\vartheta_j > 0$ is the market share weighted market power on the output market and is bound between $\left[0, \left(1 - \frac{ms_j}{\varepsilon_{jF}}\right)\right]$ while ν_j makes the function stochastic.

Following Corts (1999) and Kutlu and Sickles (2012), we may rearrange the expression $\mu(.) = 1 - \frac{ms_j}{\varepsilon_{jF}}\,\vartheta_j$ so that an average conduct parameter can be obtained by the following expression:

$$\frac{\hat{\vartheta}_{Av}}{\hat{\varepsilon}_F} = (1 - \hat{\mu})\frac{1}{ms_{Av}} \tag{18}$$

where ˆ refers to the estimate of the corresponding variable. In this sense the conduct parameter ϑ_{jt} can now be interpreted in terms of an elasticity as well as market power. Note that the aggregate demand parameter $\hat{\varepsilon}_F$ can be derived from estimating a demand function, market share ms_j is fully observed while market power $\hat{\mu}$ can be extracted from estimated supply function (Bresnahan, 1989; Corts, 1999; Kutlu and Sickles, 2012). Following Bresnahan (1982), Lau (1982), Corts (1999), and Perloff and Shen (2012), one can circumvent the need for estimating marginal cost function requiring total cost data by assuming that MC_j are constant; meaning that they do not depend on Y_j but may be a function of cost shifters. Given this assumption, equation (18) thus suggests that if MC_j and Y_j are (highly) collinear, then MC may therefore be identified through the variation in $\frac{\partial p_j(Y)}{\partial Y}$.

4. Data

The model utilises data at the consecutive points along the pork value chain. First, farm-level data are required to estimate the marginal production costs for pig farmers. Secondly, market data are necessary for the market of live pigs. Finally, agent-level data are also required for the slaughterhouses. These data cover both individual quantities and financial variables.

4.1. The situation of the pig farmers

The farm-level data is based on Flemish Farm Accounting Data Network (FADN). We consider data on specialised Belgian pig farmers. For this application, farms were considered specialised when at least 75% of their total income was based on the production of pigs. This leads to an unbalanced panel data set of 764 observations, covering the years 2001 to 2013.

The marginal costs that are included are inputs for labour, land, capital and feedstock. Land is considered as a separate factor of production. Marginal land costs for owned land are based on the value of the lands reported in the balances, and on the average interest rates for long-term deposits. This cost represents a forgone income on capital interests that are lost when investing the capital in land rather than in deposits, and is based on the average long-term revenue on deposits in Belgium. The capital inputs are maintenance of machinery-related capital and building capital as well as depreciation of capital assets based on the replacement value, and interest and financial charges paid. The feed costs include feed for pigs and poultry, and veterinary fees and reproduction costs.

The approximation of the wage costs for production cannot be based on the reported Farm Family Income (FFI). This FFI is calculated by looking at the net revenues of the farm over the year, and incorporates therefore already the market side of the equation. This would also imply that wages vary with the market prices of live pigs, assuming that the farmers accept any kind of wage following market prices. In this case, a wage independent of market dynamics has been integrated. Paid labour on the farm is accounted for in the reported balance sheets. Unpaid labour is provided by the farm family. And the upper negotiation objective of the farms includes full wages for every participating household member. For this approach, the cost of the labour input includes reported unpaid labour hours, valued according to the average gross hourly salary for artisanal labourers in Belgium.

These marginal costs define the negotiation starting point for the pig farmers. This implies that the requested remuneration is supposed to cover all costs, including financing of land, and a full wage based on the artisanal labourers' salaries. These wages are relatively low; only wages for unschooled labourers are lower. Wages for factory workers are slightly higher. But this also means that the starting position does not request wages for company executives or independent workers, even if in reality the farmers are independent company leaders.

4.2. The situation of the slaughterhouses

For the situation of slaughterhouses, a unique database of panel data on different types of information was assembled. The final panel data set contains 240 observations between 2001 and 2015 with combined slaughter data and financial data on 28 slaughterhouses. The slaughter data is based on slaughter statistics from the Belgian Food Security Agency (FAVV). Financial data is based on the official annual balances deposited at the National Bank. This database includes most of the sector's activity in Belgium. In this study, only the specialised pig slaughterhouses are considered. Specialised cattle, mixed slaughterhouses for cattle and pigs, or specialised poultry slaughterhouses are excluded from the scope of this study.

5. Results

The results for the estimations of the pig farmers' situation are reported in Table 4. The parameters $\hat{\alpha}$ and $\hat{\lambda}$ of equation (8) are used to interpret the relative dominance of farmers versus slaughterhouses in terms of market power. The link between the pork price index and the negotiation objective of the slaughterhouses, $\hat{\beta}$, can be derived from $\hat{\lambda}$. The results, using a robust ordinary least squares regression, indicate a level of $\hat{\alpha}$ equal to 75,0%***. This shows a power balance that offers a significant advantage to the pig farmers relatively to the slaughterhouses in setting the unit price p_F. In absolute values, $\hat{\alpha}$=75,0%*** remains pessimistic from the farmer's perspective. As mentioned earlier, the weight $\hat{\alpha}$ is set to a reference point of the farmer receiving a full wage that covers operating costs, a quite minimalistic starting position for the farmer. On the basis of this reference point, the market allows the farmer only to receive 75% of his or her full wage.

Figure 1 shows the evolution of the different prices in the live pig market between 2001 and 2013. It shows that the final price for live pigs follows the evolution of the marginal costs. It should be kept in mind that these marginal costs are determined based on a relatively modest wage expectation. Between 2004 and 2006, the revenues were slightly higher than this reference, indicating that the farmers were able to obtain a relatively higher wage during these years as well. All other years this wage could not be obtained. The evolution of the slaughterhouse price objective remains throughout the years well below the pig market price meaning that imperfect competition at the slaughter input market remains throughout the period.

Concerning the situation of the slaugherhouse output market (using equation 18), one can see a stable market configuration, the overall $\hat{\mu}$, for the period 2001–2015, equals 1.175%*** (standard error, 0.14%). The results per year of these estimations are reported in Table 5. These profit margins remain

very low throughout the years. Since 2004 average market share is steadily increasing, indicating the slow consolidation of the slaugtherhouse sector. However, the conduct parameter is decreasing during the same period. During this period, collusive behaviour and strategic adaptation of production quantities seem to become less attractive.

There are, however, significant differences among the market power indicators of the different slaughterhouses. The same estimation can be made for each slaughterhouse, assuming the conduct parameters for each slaughterhouse are constant during the considered time period. In that case equation (18) can be estimated using a non-linear least squares regression. Table 6 shows the results of the estimations of equation (18) when grouped by slaughterhouses over the different available years. The $\hat{\mu}$ varies between –0.96% and 3.95%, and no direct link exists with the average market share of these slaughterhouses.

This reflects a diversity of strategies within the sector. Some slaughterhouses opt for large turnover with slim margins, and reduced mark-ups (for example, slaughterhouse 11). Other slaugherhouses target very small markets with high-value products (for example, slaughterhouse 25). This diversity of strategy again reduces the possibility of collusive behaviour in the entire sector.

6. Conclusions

This model concentrates on the interaction between pig farmers and slaughterhouses. The integration of these factors in a consistent model requires detailed description of the potential decisions for each actor. This work is based on related models for agro-industrial food chains. Over the years, these experiences have enabled the application of a structural modelling approach to a wide range of different market types. The review of the sector shows that market power can potentially be exerted by different actors. This market power can take different forms. Pig farmers can obtain improved market positions by coordinating their price negotiations for the live animals. Slaughterhouses can coordinate both price and quantity. However, the slaughterhouses are constrained by the fact that their output is sold on a global market where they are essentially price takers.

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Table 1: Evolution of pig farmers and pig stock in Belgium (Statbel data)

Year	Total pig stock [1000 head]	Farms with pigs [#]
2000	7 369	10 234
2001	6 834	9 593
2002	6 735	9 163
2003	6 539	8 645
2004	6 355	8 087
2005	6 318	7 722
2006	6 295	7 361
2007	6 255	6 993
2008	6 262	6 553
2009	6 321	6 163
2010	6 430	5 891
2011	6 521	5 596
2012	6 634	5 389
2013	6 481	5 091
2014	6 350	4 825
2015	6 364	4 727

Table 2 : The number of active slaughterhouses for pigs and their market concentration.

	Number of active slaughterhouses that slaughter pigs	Number of specialised pig slaughterhouses	Market share of the specialised slaughterhouses	Average input of live animals (non-specialised slaughterhouses) [heads]	Average input of live animals (Specialised slaughterhouses) [heads]	Maximum input of live animals [heads]	HHI
2 006	64	19	81%	44 555	459 782	1 140 604	563
2 007	61	19	82%	47 176	486 403	1 155 094	570
2 008	64	19	86%	34 560	505 381	1 189 932	610
2 009	60	18	91%	24 369	563 210	1 350 932	681
2 010	55	18	86%	44 690	569 030	1 364 651	627
2 011	41	20	90%	53 696	533 657	1 363 326	647
2 012	41	19	91%	50 069	559 104	1 309 559	662
2 013	39	18	91%	51 787	603 310	1 375 713	699
2 014	39	17	91%	46 495	639 146	1 425 876	738
2 015	35	17	93%	44 822	653 675	1 410 868	792

Table 3: Difference between export of live pigs and export of pig carcasses.

	Slaughtered pigs		Net export of live pigs	Export of pork	
	Number	**Weight**		**Carcass weight**	**% of total production**
Year	[1000 heads]	[tons]	[%]	[tons]	[%]
2004	11 117	1 054 010	–1,8%	/	/
2005	10 903	1 014 623	–2,1%	508 870	50,2%
2006	10 741	1 008 037	–1,3%	605 865	60,2%
2007	11 323	1 063 278	–3,7%	651 828	61,3%
2008	11 157	1 056 169	–3,3%	662 372	62,7%
2009	11 161	1 080 527	–4,7%	696 425	64,4%
2010	11 896	1 123 767	–3,3%	707 160	62,9%
2011	11 765	1 108 254	–1,7%	678 942	61,3%
2012	11 695	1 109 610	–2,5%	687 016	61,9%
2013	11 915	1 130 572	–1,7%	715 999	63,3%
2014	11 855	1 118 325	–0,7%	695 634	62,2%
2015	11 887	1 124 310	1,0%	742 335	66,0%

Production and slaughtering data from Statbel.
Export data from VLAM (Flanders' Agricultural Marketing Board).

Table 4: Marginal cost estimates for the farmers and corresponding negotiation limits for the live pig market

		Composition of the marginal production cost								
Year	Obs	Marginal Capital cost	Marginal Labour cost	Marginal Land cost	Marginal Feed cost	Total Marginal cost $\widehat{MC_F}(V_i)$	Standard error of $\widehat{MC_F}$	Pig market price p_F	Pork consumption price index (2013=100) I_P	Slaughterhouse negotiation limit $\widehat{p_F^L}$
2001	87	25.7	32.6	4.0	95.1	157.4	4.2	161.3	76.9	106.3
2002	80	23.3	29.2	3.7	92.0	148.1	2.8	130.9	78.9	109.1
2003	69	20.6	26.8	3.1	86.4	136.9	3.3	116.8	80.5	111.4
2004	53	17.6	22.2	3.5	83.6	126.9	2.8	134.9	81.8	113.1
2005	50	18.1	22.0	3.4	77.8	121.2	2.7	132.7	83.2	115.1
2006	50	18.2	23.5	3.8	82.7	128.2	2.9	138.0	85.6	118.3
2007	49	18.8	20.1	3.7	99.5	142.1	3.4	127.2	87.6	121.2
2008	54	18.9	19.1	4.4	107.9	150.3	2.4	143.8	88.6	122.5
2009	62	21.4	20.4	4.3	92.0	138.0	2.4	133.3	89.3	123.5
2010	50	20.5	18.0	3.3	91.7	133.5	3.8	127.3	89.8	124.1
2011	55	18.9	16.8	4.2	105.7	145.6	2.0	137.3	91.2	126.1
2012	53	20.7	17.2	3.6	118.7	160.3	2.7	159.5	94.7	131.0
2013	52	22.0	17.7	3.5	123.5	166.7	3.6	156.3	100.0	138.3

Table 5: Estimations of average market shares and conduct parameters in the slaughterhouse sector

Year	ms_{Av}	$\widehat{\mu}$	**Obs**	$\frac{\widehat{\vartheta}_{Av}}{\widehat{\varepsilon}_F}$
2001	5.4%	0.94%***	14	18.47***
2002	5.3%	0.43%	15	/
2003	5.7%	0.96%***	14	17.33***
2004	4.3%	1.32%**	14	23.04**
2005	4.2%	0.95%*	13	23.33*
2006	4.5%	1.05%***	18	22.10***
2007	4.5%	1.14%***	18	22.04***
2008	4.5%	1.15%**	19	21.82**
2009	4.9%	1.07%*	19	20.00*
2010	4.7%	1.01%*	19	20.96*
2011	5.2%	1.43%***	18	18.83***
2012	5.6%	1.08%***	16	17.72***
2013	6.0%	1.21%***	15	16.48***
2014	6.4%	1.10%	14	/
2015	6.6%	0.64%	14	/

* : $p < 0.05$; ** : $p < 0.01$; *** : $p < 0.001$

Table 6 : Company-specific market power indicators

Company n°	**Obs.**	$\widehat{\mu}$	ms_j	**Company n°**	**Obs.**	$\widehat{\mu}$	ms_j
1	8	–0.96%	1.4%	15	4	0.57%***	6.4%
2	8	–0.20%	3.9%	16	5	0.58%	1.4%
3	7	–0.17%	1.9%	17	5	0.89%***	4.8%
4	2	–0.11%	1.6%	18	15	0.94%***	7.7%
5	15	–0.11%	8.3%	19	7	1.06%	1.1%
6	10	0.03%	5.9%	20	10	1.23%***	4.8%
7	5	0.03%	2.5%	21	5	1.30%**	1.8%
8	15	0.08%	2.9%	22	15	1.72%***	4.9%
9	10	0.13%	2.7%	23	5	2.33%**	1.4%
10	5	0.16%**	9.0%	24	8	2.66%	0.4%
11	10	0.28%***	11.1%	25	15	3.50%***	6.3%
12	3	0.37%	3.7%	26	15	3.68%***	10.9%
13	8	0.39%	5.6%	27	15	3.98%***	6.1%
14	10	0.42%	2.8%	**Total sample**	**240**	**1.18%**	**5.2%**

* : $p < 0.05$; ** : $p < 0.01$; *** : $p < 0.001$

Figure 1: Comparison of the marginal production costs of pigs with the live pigs price, and the negotiation objective of the slaughterhouses