Investigating market power in the Belgian pork production chain[1]

AUTHORS

Dries Maes[1], Mark Vancauteren[1,2], and Steven Van Passel[1,3]

Corresponding author: Dries Maes, e-mail: dries.maes@uhasselt.be

[1] Research team Environmental Economics, Universiteit Hasselt, Agoralaan Building D, 3590 Diepenbeek, Belgium

[2] Statistics Netherlands(CBS), Henri Faasdreef 312, 2492 JP Den Haag, Netherlands

[3] Department of Engineering Management, University of Antwerp, Prinsstraat 13, 2000 Antwerpen, Belgium

Paper prepared for presentation at the 149th EAAE Seminar 'Structural change in agri-food chains: new relations between farm sector, food industry and retail sector' Rennes, France, October 27-28, 2016

[1] The current version is a preliminary version, and changes to the model construction are still possible following data availability.

Abstract

The Belgian pig production has been confronted with stagnating prices since the start of the century. While several studies have investigated the financial structure of the pork production chain, 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 looks at potential oligopolies and oligopsonies in the pork production sector. A new model is build 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 slaughterhouses data for the period 2002-2011. The potential reasons and consequences of these market powers are discussed.

Keywords: Market power, slaughterhouse, input elasticity, mark-up

1. Introduction

Prices for meat products have been stagnating for years in Belgium. Both the animal raising farms 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 specializing in animal products. Official reports have been commissioned to review average farm profitability (Deuninck, D'Hooghe and Oeyen 2009). Farms specializing 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 specializing 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 faces 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, FOD Economie, 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. Market power investigations can provide valuable information for these discussions. This article applies a market power analysis, and focuses specifically on the role of the slaughterhouses, investigating potential oligopolic and oligopsonic behaviour.
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 1 346 in 2015. This continued consolidation reduced the total number of pig farmers. But the large amount of farmers is no directly an indication of market concentration. The farmers are however well organised. There are two farmer's unions with considerable operational and political power, and a specific union for pig producers is equally active to improve the working conditions in this sector.

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

In Belgium, all pigs are slaughtered in registered slaughterhouses. The role of slaughterhouses is thus pivotal in the meat supply chain. Unlike the situation in other countries (Hayenga, Schroeder, Lawrence, Hayes, Vukina, Ward and Purcell, 2000, Schulze, Spiller and Theuvsen, 2006), strong vertical integration in Belgium is not common. The slaughterhouse sector in Belgium is highly diverse and contains 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, only approximately 90 large active sites remained in 2011. Still, this number remains sufficiently high to allow a diverse sector that does not show signs of excessive concentration. Table 2 reports the numbers of active slaughterhouses for pigs, based on official data from the Federal Agency for Safety of the Food Chain (FAVV). The smallest entities, with less 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. Two of these mixed slaughterhouses are still officially a municipal service. 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 index (Hirschman, 1964), indicates a slow and gradual consolidation for pig slaughterhouse sector.

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 [heads]	Maximum input of live animals [heads]	HHI
2 006	64	19	81%	171 055	1 140 604	563
2 007	61	19	82%	189 092	1 155 094	570
2 008	64	19	86%	182 134	1 189 932	610
2 009	60	18	91%	199 469	1 350 932	681
2 010	55	18	86%	219 371	1 364 651	627
2 011	51	16	87%	232 532	1 476 973	680

The original motive of this research is the continued low price level for live pigs. The model focuses on the dynamics of this price determination. The price setting in 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 between farmers and regions. Certainly during the last decade, price differences among farmers for live pigs have 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 hold discussions 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 received after negotiation. These prices differ little from the published prices and closely follow the average prices throughout the year. Table 3 reports the average annual input prices for live cows and live pigs.

Table 3 : Yearly average nominal prices for live pigs [EUR]

Year	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
[EUR]	135,1	161,3	130,9	116,8	134,9	132,7	138,0	127,2	143,8	133,3	127,3	137,3	153,6	150,4	136,4	121,9

Secondly, the slaughterhouses stress that negotiations with farmers are hard. The 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 amount 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 the price setting. During negotiation 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. There is very little actual export of live animals to these countries. But the sales of pig carcasses happens on an open global market. Most of the produced pork is intended for export. These tendencies are illustrated in Table 4. A minimal net import of live pigs is present in Belgium. On the other hand, the export of carcasses is very important. Over 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.

Table 4: Difference between export of live pigs and export of pig carcasses.

	Slaughtered pigs			Export of pork	
	Number	Weight	Net export of live pigs	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).

The remainder of the text is structured as follows. Section 2 describes the construction of the model that reflects the specific market characteristics for live animals and meat products in Belgium. Section 3 provides results, and an interpretation of the variables. Section 4 concludes.

2. Model construction

The overview of the different actors and tendencies allows 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 the research lies on the dynamics in the market of live pigs, 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 by 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. This is unlikely in theory, as quantity agreements involve a limited number of partners. With over 4.000 farms, a coordinated control of the quantity of produced live pigs would leave a too large incentive for free riders. This is also unlikely in practice. 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.

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

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

For this study, a unique database of panel data on different types of information was assembled. The final panel data set contains 198 observations between 2002 and 2011 with combined slaughter data and financial data on 21 slaughterhouses. This database includes most of the sector's activity in Belgium. In this study, only the specialised pig slaughterhouses are considered. Specialized cattle, mixed slaughterhouses for cattle and pigs ore specialized poultry slaughterhouses are excluded from the scope of this study.

2.1. 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, Karp and Golan, 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, Kim and Raju, 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 the output market has frequently been applied in agricultural markets (Myers, Sexton and Tomek, 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 U.K. beef market. Applications also looked at mark-ups in Australia (Chung and Griffith, 2009) or the Ukraine (Perekhozhuk, Matyukha and Glauben, 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, Glauben, Teuber and Grings, 2014). 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, Azzam and Lirón-España, 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 to investigate the evolution of market powers in the U.S. beef packing industry. For instance, other applications showed the evolution of both mark-ups and markdowns in the U.S. 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). 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, Morgan and Rayner, 2001, Weldegebriel, 2004) and in practice (Gonzales, Guillotreau and Le Grel, 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 indicated 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, Sexton and Tomek, 2010). In each case, the results are useful starting points for more detailed analyses, subsequently modelling a specific market configuration.

2.2. 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 at the supply side can be compensated by similar behaviour at the demand side. This type of analysis has first been proposed by Azzam (1996). This approach for instance has been applied to the Danish pork production chain (Jensen, 2009), or to optimise marketing for food retailing (Chung, Eom and Yang, 2014). Kinoshita, Suzuki and Kaiser (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 at international markets for food products. An adapted model is therefore constructed for this case.

For the market of live pigs, we have to 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 products is defined by:

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

Here, α is the indicator for the vertical market power of the farm cooperatives. p_F is the final price for live pigs, and 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 on this market. This price is determined based on the cost structure of the pig farmers. p_F^{Lower} on the other hand is the lowest price the pig slaughterhouses would obtain for their input in the case they would be the sole price setters. This price is determined by the production and cost structure of the slaughterhouses.

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

$$\pi_i = p_F q_i - C_F(V_i) \quad (2)$$

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

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

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

where MC_F is the marginal production cost at the farm, ms_{Fi} is the market share of farm i, ε_{SF} is the price elasticity of supply, and η_F 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 measures therefore collusive behaviour. In literature, there is an increasing tendency to interpret this rather as a general market power parameter with range $[0, 1/ms_{Fi}]$ (Sexton, Sheldon, McCorriston and Wang, 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, t.i. 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.

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

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

Here, w_{Fi} are price indexes for $i \in$ (Land, Capital, Labour, Fytoproducts). This approximation can be done based on the individual farm-level data from FADN.

2.3. The pig slaughterhouses

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

$$Y_{it} = A_{it} F_i(\boldsymbol{X_{it}}) \qquad i = 1,2,\ldots N;\, t = 1,...,T, \tag{6}$$

where Y_{it} measures firm i's gross output, $\boldsymbol{X_{it}} \equiv (X_{i1t}, X_{i2t}, \ldots, X_{iJ_it})'$ denotes the vector of J_i nonnegative factor inputs (capital, labor,…), $F_i(.)$ is the core of the (differentiable) production function, and A_{it} is Total Factor Productivity (TFP) measured as the rate of a Hicks-neutral disembodied technology. Logarithmic differentiation of production function (1) yields:

$$\frac{dY_{it}}{Y_{it}} = \frac{dA_{it}}{A_{it}} + \sum_{j=1}^{J_i} \frac{X_{ijt}}{F_i(\cdot)} \frac{\partial F_i(\cdot)}{\partial X_{ijt}} \frac{dX_{ijt}}{X_{ijt}} \tag{7}$$

with $\frac{dY_{it}}{Y_{it}}$ (logarithmic) output growth and $\frac{\partial \log Y_{it}}{\partial t} = \frac{dA_{it}}{A_{it}}$ (logarithmic) TFP growth.

It is assumed that each firm i faces an inverse demand function, $p_{it}(Y_t, Z_t)$, which represents the market price as a function of aggregate (industry) output $Y_t \equiv_{i=1}^{N} Y_{it}$, i.e., by specifying firm i's (output) price as an arbitrary function of aggregate output we allow for various potential degrees of firm i's market power, and Z_t is vector of demand related variables (here we need to specify for instance, the world price as well as other market demand related variables).

Firm i's optimization problem can be written as:

$$\max_{Y_{it}, \mathbf{X}_{it}} \left[\left(p_{it}(Y_t, Z_t) - p_F^{Lower}(Y_t, Z_t) \right) Y_{it} - \mathbf{V}_{it}' \mathbf{X}_{it} \mid Y_{it} = A_{it} F_i(\mathbf{X}_{it}) \right] \tag{8}$$

where $V_{it} \equiv (V_{i1t}, V_{i2t}, \ldots, V_{iJ_it})'$ is firm i's vector of J_i input prices. $p_F^{Lower}(Y_t, Z_t)$ is the lowest price the pig slaughterhouses would obtain for their input of live pigs, if they were price setter on that market.

Assuming, in the first instance, that there is imperfect competition on the input market and perfect competition on the output markets (a oligopolistic firm acting as a price-setter on its input market and a price-taker on its output markets), the first order conditions (FOCs) implied by the solution of (8) yield the following equations for the Lagrange multiplier and the nominal input prices:

$$p_{it}(Y_t,Z_t) - p_F^{Lower}(Y_t,Z_t) - \frac{\partial p_F^{Lower}(Y_t,Z_t)}{\partial Y_t}\frac{\partial Y_t}{\partial Y_{it}}Y_{it} = p_{it}^{*} \text{ and}$$

$$\left[p_{it}(Y_t,Z_t) - p_F^{Lower}(Y_t,Z_t) - Y_{it}\frac{\partial p_F^{Lower}(Y_t,Z_t)}{\partial Y_t}\frac{\partial Y_t}{\partial Y_{it}}\right]\frac{\partial Y_{it}}{\partial \mathbf{X}_{it}} = \mathbf{V}_{it}, \quad (9)$$

where, according to Diewert (1993) and Diewert and Fox (2004), the Lagrange multiplier p_{it}^{*} is firm i's shadow or marginal price of output under profit maximization and market power enables firm i to set each input's marginal product, $\frac{\partial Y_{it}}{\partial X_{ikt}}$, above the respective factor cost. Let $ms_{it} = \frac{Y_{it}}{Y_t}$ is the market share of firm i at time t; $\varepsilon_{iF} \equiv -\frac{\partial Y_t}{\partial p_{iF}(Y_t,Z_t)}\frac{p_{iF}(Y_t,Z_t)}{Y_t}$ is the (absolute value of) elasticity of supply in the input market; $\vartheta = \frac{\partial Y_t}{\partial Y_{it}}$ is the conduct parameter. The solution to the profit maximization as shown in equation (9) can be rewritten as:

$$p_{it}^{*} = p_{it} - p_F^{Lower} - \frac{\partial p_F^{Lower}}{\partial Y_t}\frac{\partial Y_t}{\partial Y_{it}}Y_{it} \quad (10)$$

$$= p_{it} - p_F^{Lower}\left(1 - \frac{ms_{it}}{\varepsilon_{iF}}\vartheta_{it}\right) \quad (11)$$

where the term between square brackets is firm i's *markup* in the input market. Note that in case of perfect competition $\frac{\partial p_{it}(Y_t)}{\partial Y_t}$ goes to zero, implying that prices are set at marginal cost since marginal revenue (MR_{it}) is (always) equal to marginal cost (MC_{it}) (or $MR_{it} = p_{it}^{*} = MC_{it}$) and inputs are paid their marginal products (markup equal to 1) then.

2.4. Identification

An approach for measuring market power is to measure the conduct parameter ϑ_{it} instead of the Lerner index (Bresnahan, 1989, Corts, 1999). As in Kutlu and Sickles (2012), the definition of MC follows from equation (11) when inputs are paid their marginal products:

$$MC_{it} = p_{it} - p_F^{Lower}\left(1 - \frac{ms_{it}}{\varepsilon_F}\vartheta_{it}\right) \quad (12)$$

where $\varepsilon_{iF} \approx \varepsilon_F$ is the elasticity of aggregate input supply. Loglinearizing, rearranging equation (6) and adding a stochastic error, v_{it} yields the following supply relation:

$$\ln p_F^{Lower} = -\ln\left(1 - \frac{ms_{it}}{\varepsilon_t}\vartheta_{it}\right) + \ln(p_{it} - MC) + v_{it} \quad (13)$$

In order to identify the model, in most of the NEIO empirical applications, marginal costs can be estimated on the basis of a cost function which is usually accompanied with a supply and a demand function so identify the parameters of conduct ϑ_{it} as well as the Lerner index. The parameter ϑ_{it} nests several market structures. In case of perfect competition, $\vartheta_{it} = 0;$ under symmetric Cournot competition, $\vartheta_{it} = 1/n$ where n are the number of firms in the market and under a pure monpoly $\vartheta_{it} = 1$.

Following Kutlu and Sickles (2012), we may rewrite expression (13) as,

$$\ln p_F^{Lower} = \mu(ms_{it}\vartheta_{it}, \varepsilon_t) + \ln(p_{it} - MC) + \nu_{it} \tag{14}$$

$$\ln p_F^{Lower} = z^* + \ln(p_{it} - MC) + \nu_{it} \tag{15}$$

where $\mu^* \equiv \mu(.) = -\ln\left(1 - \frac{ms_{it}}{\varepsilon_F}\vartheta_{it}\right) \geq 0$ is the market share weighted market power on the output market and is bounded between $[0, \; -\ln\left(1 - \frac{1}{\varepsilon_F}\right)]$ while ν_{it} makes the function stochastic. If we allow the vector Z_t demand-related variables to be used as explanatory variables or as proxies for market power we can get an estimate for $\hat{z}$ which enables us to obtain an estimate for the conduct parameter ϑ_{it}. 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_{it} are constant; meaning that they do not depend on Y_{it} but may be a function of cost shifters. Given this assumption, equation (12) therefore suggests that if MC and Y_{it} are (highly) collinear, then MC may therefore be identified through the variation in $\frac{\partial p_{it}}{\partial Y_t}$.

Following Corts (1999), and Kutlu and Sickles (2012), we may rearrange the expression $\mu(.) = -\ln\left(1 - \frac{ms_{it}}{\varepsilon_F}\vartheta_{it}\right)$ so that a conduct parameter can be obtained by the following expression:

$$\hat{\vartheta}_{it} = \frac{\hat{\varepsilon}_F}{ms_{it}}(1 - \exp(-\hat{\mu})) \tag{16}$$

where $\hat{}$ refers to the estimate of the corresponding variable. In this sense the conduct parameter ϑ_{it} can now be interpreted in terms of an elasticity as well as market power. The aggregate demand parameter $\hat{\varepsilon}_F$ can be derived from estimating a demand function, market share ms_{it} is fully observed while market power $z(.)$ can be extracted from estimated supply function (Bresnahan, 1989, Corts, 1999, Kutlu and Sickles, 2012) that includes X_g demand variables.

2.5. The estimation of the demand and supply

With data on the total costs, marginal costs can be estimated on the basis of a cost function. Estimation of most empirical applications of this type, which does not require the constant MC assumption, is done in a simultaneous system that includes a cost function as well as demand and supply function in order to identify the parameter of conduct ϑ_{it} and the elasticity of supply ε_F. Following this appoach, the MC_{it} is obtained by estimating a (e.g. flexible) cost function,

$$C_{it} = f_i(\alpha_v \boldsymbol{V}_{it}, \alpha_{Y,} Y_{it}) \tag{17}$$

where the parameter α_x is the corresponding coefficient of the variable X. Following, amongst others, (Delis and Tsionas, 2009, Uchida and Tsutsui, 2005), we can rearrange equation (12) and define firm's revenue as $R_{it} \equiv p_{it} Y_{it}$ so that we can specify a supply function of the following generic form,

$$R_{it} = f_i(\alpha_R, ms_{it}, \hat{\alpha}_{1,Y,}, Y_{it}, C_{it}) \tag{18}$$

where $\alpha_R = \frac{\vartheta_{it}}{\varepsilon_t}$, and $\hat{\alpha}_Y, Y_{it}, C_{it}$ are obtained by substituting the the variables and parameters of equation (17) into the derivative of equation (12) given that $MC_{it} \equiv \frac{\partial Y}{\partial C}$.

In order to identify ϑ_{it} separably from ε_F, we may specify an inverse demand function,

$$p_{it} = f_i(\alpha_{1,Y}, Y_t, \alpha_{1,Z}, Z_t) \tag{19}$$

where $\alpha_{1,Y} \equiv -\frac{1}{\varepsilon_t}$ and Z are exogenous demand shifters. This importance of this approach is that it allows a direct integration of the internal dynamics on the market, with the influence of external factors that are of importance in this setting. For instance, live pig prices in neighbouring countries are important benchmarks during negotations. Given the large export share of the pig carcasses, fuel prices for transport, as well as global meat demand indicators are essential to relate global changes with fluctuations in the price dynamics at the local market. It is also noted that the relationship between efficiency and competition should be taken into account in the analysis.

3. 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.

Acknowledgements

Part of this work contributes to the H2020 project SUFISA "Sustainable finance for sustainable agriculture and fisheries" and has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 635577. Prof. Steven Van Passel thanks DG Agriculture (European Commission) for access to the Farm Accountancy Data Network (FADN). All remaining errors are the sole responsibility of the authors.

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