What does the stochastic frontier estimator of market power really account for? A theoretical analysis with references from the food industry.

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Abstract

The objective of this study is to demonstrate that the recently developed stochastic frontier (SFA) estimator of market power measures mark–ups in the output market, as the seminal paper demonstrates, only under a specific market structure. The measurement of market power along the food marketing channel is employed in order to derive our theoretical findings. The results indicate that, without prior knowledge of the structure of the market under investigation, it is only safe to say that the SFA estimator of market power measures the sum of oligopolistic and oligopsonistic distortions.

Keywords: stochastic frontier estimator; market power; food industry.
JEL classification: D21, L22, L66.

1. Introduction

In their recent study, Kumbhakar, Baardsen and Lien (2012) draw on the stochastic frontier methodology from the efficiency literature (Coelli et al., 2005; Kumbhakar and Lovell, 2003) and develop a stochastic frontier (SFA) estimator of market power in order to estimate mark–ups in an output market. One of the big advantages of the SFA estimation technique is that it allows us to estimate market power under constant or variable returns to scale, which is not always the case in the New Empirical Industrial Organization (NEIO) approach, providing us with more flexibility in the measurement of markups of an industry. Furthermore, the SFA methodology estimates mark–ups directly instead of the market structures that the mark–ups arise from (Lopez et al., 2017). Accordingly, the estimation of conduct (conjectural variations) is not a requirement anymore in order to proceed with the estimation of market power and/or the Lerner index for the market under examination.

The starting point of Kumbhakar et. al.'s (2012) theoretical model is the inequality $P > MC$, which indicates that a firm with oligopolistic power sets price (P) above its marginal cost of production (MC). Multiplying both sides of the inequality by (Y/C), where Y is the firm's output and C is the firm's total cost, the inequality is converted into the following equality:

$$\frac{PY}{C} = \frac{dlnC}{dlnY} + u, \quad u \geqslant 0 \tag{1}$$

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where $\frac{PY}{C}$ is the revenue share in total cost, $\frac{dlnC}{dlnY}$ is the scale elasticity and u is a nonnegative one–sided term that measures the mark–up in the output market. In their original work, the authors prove how the term u is equivalent to the nonnegative one–sided random variable associated with technical inefficiency. Hence, Kumbhakar et al. (2012) estimate u by employing estimation techniques from the stochastic frontier methodology and the efficiency literature. The SFA estimator of oligopolistic power is derived with the help of the estimated value of the term u.

Subsequently, the authors applied their new methodology in order to estimate the mark-up in the Norwegian saw-milling industry. Sawmills process a primary input (sawlogs) and convert this raw input into sawn timber (processed output). Sawn timber may also be used as an intermediate output or as an input in the saw-milling industry. In this particular supply chain, saw-milling firms play the role of a processor (wholesaler): they purchase an input from an industry upstream and sell the processed output to an industry downstream. Hence, saw-milling firms might exercise oligopsonistic power when purchasing the primary input (sawlogs) as well as oligopolistic power when selling their processed output (sawn timber). Regarding the sawlogs (input) market, Størdal and Baardsen (2002) tested for the presence of market power. Their empirical results were based on mill–level data and revealed that Norwegian sawmills exercised oligopsonistic power in the input market for sawlogs for the time period 1984–1991. Since previous studies had tested and found statistical significant evidence of market power in the input (sawlogs) market, Kumbhakar et al. (2012) applied their SFA estimation technique in order to estimate oligopolistic power in the Norwegian sawmilling output market. For the empirical implementation the authors employed a translog cost function. Their empirical results reveal statistically significant evidence of oligopolisitc power exercised by the sawmilling firms, since the value of the mark–up term u in equation 1 is statistically different than zero.

Bairagi and Azzam (2014) used the stochastic frontier estimator in order to test if the Grammen Bank exercises market power over borrowers. The authors employed a stochastic translog cost function. More specifically, the authors used annual time series for the 1985-2012 period in order to test whether the Grameen Bank's lending rates are consistent with marginal cost pricing. Their results indicated that on average the lending rate is about 3% above marginal cost.

Two studies, that have used the stochastic frontier estimator to measure market power, relate to the food industry. In the former, Lopez et al. (2017) used the stochastic frontier approach in order to estimate oligopoly power in the U.S. food industry for the period 1990–2010. The stochastic frontier estimator of market power was evaluated with the use of panel data in 42 U.S. food processing industries at the six digit Standard Industrial Classification System (SIC) provided by the NBER-CES Manufacturing Industry Database. The estimated value of the overall average degree of Lerner index was approximately 21%, indicating that all 42 food industries, in the sample, exercise some degree of oligopoly power. In the latter, Panagiotou and Stavrakoudis (2017) used a stochastic production frontier estimator in order to estimate the mark-down in an input market. The methodology was subsequently employed in order to estimate the degree of oligopsony power in the U.S. cattle industry. The empirical findings indicated that beef packers exerted market power when purchasing live cattle for slaughter. The Lerner index–based on the SFA estimator– was found to be 22.9%.

The objective of this study is to demonstrate that, in a theoretical framework like Kumbhakar et al. (2012) describe, the term u and the SFA estimator of market power measure total market power, meaning both oligopolistic and oligopsonistic power, instead of just the mark–up in the output market as proposed by the authors. The SFA estimator of market power can be given the interpretation of a mark–up only under a specific market structure. Hence, interpreting the term u of equation 1 only as a mark–up measure can bias our predictions regarding the source of market power of the market under investigation.

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$$\frac{PY}{C} = \frac{dlnC}{dlnY} + u, \quad u \geqslant 0 \tag{2}$$

where $\frac{PY}{C}$ is the revenue share in total cost, $\frac{dlnC}{dlnY}$ is the scale elasticity and u is a nonnegative one–sided term that measures the mark–up in the output market. In their original work, the authors prove how the term u is equivalent to the nonnegative one–sided random variable associated with technical inefficiency. Hence, Kumbhakar et al. (2012) estimate u by employing estimation techniques from the stochastic frontier methodology and the efficiency literature. The SFA estimator of oligopolistic power is derived with the help of the estimated value of the term u.

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$$\frac{PY}{C} = \frac{dlnC}{dlnY} + u, \quad u \geqslant 0 \tag{3}$$

where $\frac{PY}{C}$ is the revenue share in total cost, $\frac{dlnC}{dlnY}$ is the scale elasticity and u is a nonnegative one–sided term that measures the mark–up in the output market. In their original work, the authors prove how the term u is equivalent to the nonnegative one–sided random variable associated with technical inefficiency. Hence, Kumbhakar et al. (2012) estimate u by employing estimation techniques from the stochastic frontier methodology and the efficiency literature. The SFA estimator of oligopolistic power is derived with the help of the estimated value of the term u.

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2. Theoretical framework

Consider an industry in which N firms process a primary input and produce a homogeneous good Q, where Q= $\sum_{i=1}^{N} q_i$. The inverse wholesale demand for the good is given by:

$$P = P(Q), \tag{4}$$

where P is price.

We assume that processors have market power in the output market as well as in the primary input market. Without loss of generality, we consider the case where the primary factor of production is a farm input.[1] Transformation of the product from farm to wholesale units is one of fixed proportions. Hence, farm and wholesale quantities can be measured, with appropriate conversion, by the same variable Q.[2]

Technology for i^{th} processor is represented by the processing cost function K(q_i,w,τ), where w is a vector of non-farm input prices and τ captures the state of technology. The primary input is supplied by a price-taking farm industry upstream with marginal cost MC(Q, f, τ), where f is a vector of prices of factors used in the production of the farm input. The total cost (C) for the i^{th} processor, when producing output q_i, is the sum of the costs from the purchase of the farm input plus the costs of processing that are captured by K(q_i,w,τ). Profits for i^{th} processor equal to:

$$\Pi_i = P(Q)\ q_i - MC(Q,f,\tau)\ q_i - K_i(q_i,w,\tau) \tag{5}$$

Each processor chooses q_i to maximize profits. The first order condition is:

$$\frac{\mathrm{d}\Pi_i}{\mathrm{d}q_i} = \frac{\mathrm{d}}{\mathrm{d}q_i}[P(Q)\,q_i] - \frac{\mathrm{d}}{\mathrm{d}q_i}\ [MC(Q,f,\tau)\,q_i] - \frac{\mathrm{d}}{\mathrm{d}q_i}K_i(q_i,w,\tau) = 0 \tag{6}$$

Equation 4 yields:

$$P - \frac{1}{\eta}\ \frac{q_i}{Q}\ \theta_i - MC(Q,f,\tau) - q_i\ MC'(Q,f,\tau)\ \phi_i - K_i'(q_i,w,\tau) = 0 \tag{7}$$

where $\eta = -\frac{dQ/dP}{Q}$ is the semi-elasticity of demand, θ_i is the conjectural variation for the ith processor in the output market, ϕ_i is the conjectural variation for the i^{th} processor in the farm input market, $MC'(Q,f,\tau)$ is the slope of the marginal cost corresponding to the price-taking farm industry and $K_i'(q_i,w,\tau)$ is the marginal processing cost of the i^{th} processor.

Re-arranging equation 7 we get:

$$P = MC(Q,f,\tau) + K_i'(q_i,w,\tau) + \frac{1}{\eta}\ \frac{q_i}{Q}\theta_i + q_i\ MC'(Q,f,\tau)\ \phi_i \tag{8}$$

The first two terms on the right hand side of equation 8 capture the total marginal cost incurred by the i^{th} processor when producing output q_i. The expression $MC(Q,f,\tau)$ is the marginal cost of the farm input purchased by the i^{th} processing firm from the price-taking farm industry upstream. Hence, $MC(Q,f,\tau)$ represents the price paid for each unit of the farm input. The expression $K_i'(q_i,w,\tau)$ is the marginal processing cost incurred by the i^{th} processor in order to produce q_i after he/she has purchased the primary input.[3] Hence, the total marginal cost for the i^{th} processor when producing output q_i is given by:

$$TMC(q_i) = MC(Q,f,\tau) + K_i'(q_i,w,\tau) \tag{9}$$

The last two terms on the right hand side of equation 8 measure oligopolistic and oligopsonistic power respectively. More specifically, the expression $\frac{1}{\eta}\frac{q_i}{Q}\theta_i$ accounts for the market power exercised in the output market by the i^{th} processor. Parameter θ_i captures the increase in total processed output at industry level induced by an increase in processor i's output. On the other hand, the expression $q_i\,MC'(Q,f,\tau)\,\phi_i$ accounts for the market power exercised by the i^{th} processor in the input market. Parameter ϕ_i captures the increase in the aggregate supply of the farm input induced by an increase in processor i's demand for this primary input. The parameters θ_i

and ϕ_i assume positive values. If both parameters θ_i and ϕ_i are zero, then price equals marginal cost and there is no market power exercised by the i^{th} processor in the output market as well as in the input market.

Equation 8, with the help of Equation 9, is written as:

$$P - TMC(q_i) = u_i^{oligopoly} + u_i^{oligopsony} \tag{10}$$

where $u_i^{oligopoly} = \frac{1}{\eta}\ \frac{q_i}{Q}\ \theta_i$ and $u_i^{oligopsony} = q_i\, MC'(Q, f, \tau)\phi_i$.

Both terms, $u_i^{oligopoly}$ and $u_i^{oligopsony}$, are positive.[4] Hence, we can write the following inequality:

$$\begin{aligned} P - TMC(q_i) &> 0 \\ P > TMC(q_i) \end{aligned} \tag{11}$$

Inequality 9 is the starting point of Kumbhakar et. al.'s (2012) theoretical model, indicating that a firm with market power in the output market sets price above its total marginal cost of production. Following Kumbhakar et. al.'s (2012) methodology, we multiply both sides of the inequality by $(\frac{q_i}{C_i})$ and convert the above inequality into the following equality:

$$\frac{P\, q_i}{C_i} = \frac{dlnC_i}{dlnq_i} + u_i, \qquad u_i \geqslant 0 \tag{12}$$

where

$$u_i = \frac{q_i}{C_i}(u_i^{oligopoly} + u_i^{oligopsony}) \tag{13}$$

Representing the processing cost function in a translog form and following Kumbhakar et. al.'s (2012) methodology, we can estimate the nonnegative one–sided term u_i of equation 12 and interpret it as the mark–up in the output market, just like the seminal article does.[5] But, that would be the case only under a specific market structure. Equation 13 shows that the term u_i accounts for both oligopolistic and oligopsonistic distortions, since it is a function of the terms $u_i^{oligopoly}$ and $u_i^{oligopsony}$. Hence, the interpretation of u_i as a measure of market power in the output market can lead us to biased predictions regarding the source of market power of the market under examination. Starting from the basic inequality ($P > MC$) as the seminal paper does, the term u_i, as this study points out, is associated with three distinct market structures. Each market structure provides a different interpretation for the term u_i.

Proposition 1: The i^{th} processing firm has market power in the output market and no market power in the input market ($u_i^{oligopsony} = 0$). In this case, u_i captures only the mark–up in the output market and the SFA estimator measures oligopolistic mark up just like Kumbhakar et. al.'s (2012) model.

Proposition 2: The i^{th} processing firm has market power in the input market and no market power in the output market ($u_i^{oligopoly} = 0$). In this case, u_i captures only the mark–down in the input market and the SFA estimator measures oligopsonistic power. Starting from inequality 9 and following Kumbhakar et. al.'s (2012) methodology we would have estimated the nonnegative one-sided term u_i but we would have interpreted it as a measure of the mark–up in the output market when in reality it measures the mark–down in the input market. Hence, we would have concluded that processor i has oligopolistic power instead of oligopsonistic power.

Proposition 3: The i^{th} processing firm has market power in the output market as well as in the input market. In this case, the term u_i measures the sum of the mark–up in the output market along with the mark–down in the input market, indicating that the processor exercises market power when purchasing the farm input as well as when selling the processed output. Under this market structure, the SFA estimator measures the aggregate market power, namely the sum of oligopolistic and oligopsonistic power exercised by the i^{th} processor. Again, our starting point would have been inequality 9. Following Kumbhakar et. al.'s (2012) approach we would have estimated the nonnegative one-sided term u_i, but interpreted it only as a measure of the mark–up in the output market. That would bias our results, because the term u_i measures both the mark–up in the output market and the mark–down in the input market. Hence, we would have concluded that the i^{th} processor has only oligopolistic power when in reality the processor exercises both oligopolistic and oligopsonistic power.

Figure 1 presents graphically the three different market structures.[6] As we can observe, price is above marginal cost in all three different market structures. The main difference lies in the interpretation of the term u.

Panel (a) corresponds to proposition 1, where the term u measures only the mark–up in the output market. Panel (b) corresponds to proposition 2, where the term u measures only the mark–down in the input market. Finally, panel (c) corresponds to proposition 3, where the term u accounts for the sum of the mark–up in the output market and the mark–down in the input market.

3. Discussion

Since the late 1980s, the NEIO has dominated the food economics literature on the measurement of market power (Kaiser and Suzuki, 2006; Saitone and Sexton, 2012; Sexton, 2000). Overall, the NEIO studies find a significant degree of market power –oligopolistic as well as oligosponistic – in the food industries (Azzam, 1998; Lopez et al., 2002; Sheldon and Sperling, 2003).

Kumbhakar, Baardsen and Lien (2012) developed a SFA estimator of market power in order to estimate the mark-ups in as output market. One of the big advantages of the SFA estimation technique is that it bypasses the estimation of demand and conduct required in NEIO to measure the gap between price and marginal cost of production (Lopez et al., 2017).

Given the importance of the food industry to the economy and the long-standing interest of anti-trust authorities in mitigating anticompetitive behavior in the food sector, the measurement of market power and its economic consequences will continue to be re-examined in the food economics literature and be a subject of major policy concern. For example, high levels of concentration in the U.S. meat packing industry and the impact of market power on the welfare of the participants have been the issue of public debate even at the level of the U.S. Congress. As a con-

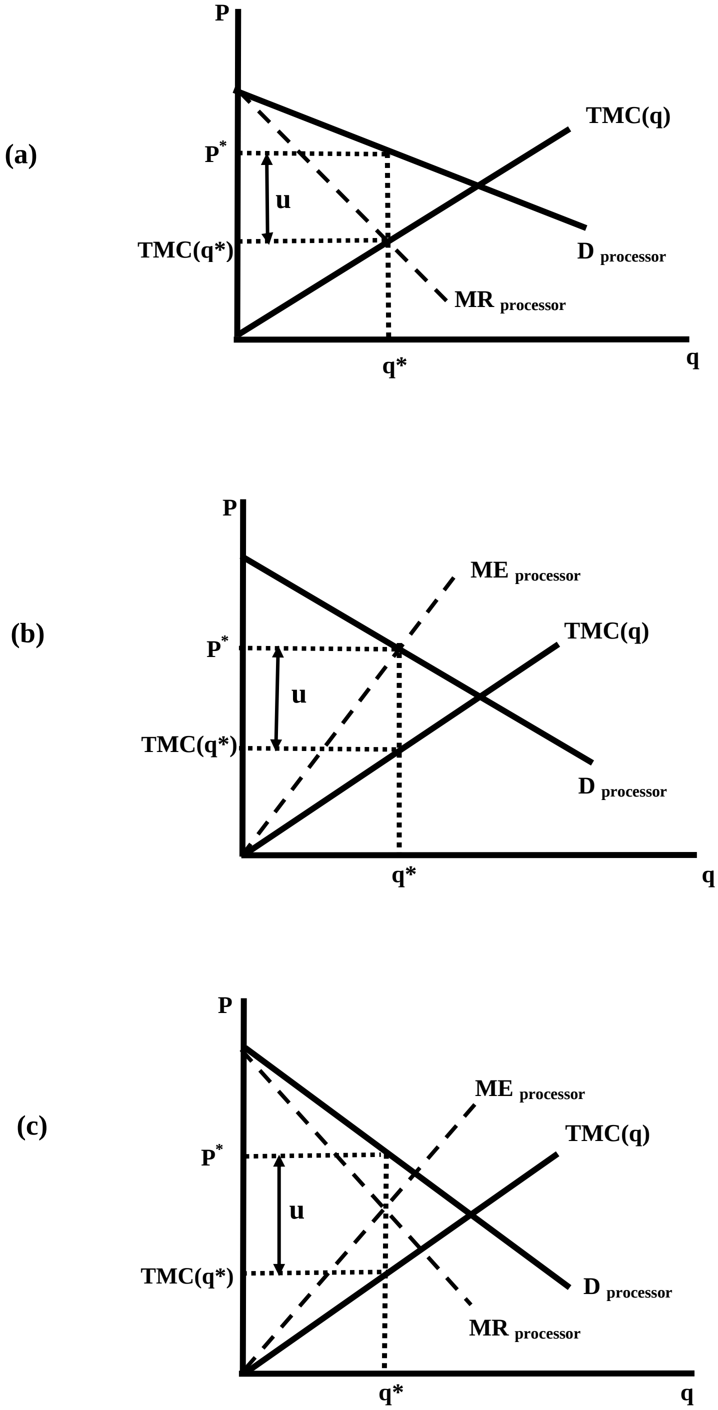

Figure 1: Food supply chain at processing level

sequence, in 1999, the U.S. Congress passed the Livestock Mandatory Reporting (LMR) Act. The main objective of the LMR Act is to encourage competitive behavior along the meat marketing channel, by providing more information to all the market participants.

As the findings of the present work indicate, in a purely theoretical framework we can identify each market structure and interpret the term u_i (or u) accordingly. Problems arise in empirical studies, especially when we employ the SFA estimation technique to estimate market power that intermediary/processing firms exercise when purchasing a primary input (i.e. farm input) from an industry upstream and concurrently sell the processed output to an industry downstream. The inequality $P > MC$ in Kumbhakar et. al.'s (2012), which indicates that a firm with market power sets price above its marginal cost of production, according to the findings of this article can be the starting point for the measurement of market power in three different market structures: a) oligopoly (mark–up in the output market), b) oligopsony (mark–down in an input market), and c) the sum of oligopolistic and oligopsonistic power (the sum of the mark–up and the mark–down). Without having tested in advance for the presence of market power exercised by the i^{th} processor in the output and/or in the input market, it is only safe to interpret the term u_i as the sum of oligopolistic and oligopsonistic power. Any other interpretation of the nonnegative one–sided term u_i can lead us to biased predictions regarding the structure of the market(s) under investigation. The identification of the source of market power – oligopolistic, oligopsonistic or both – has significant implications for the welfare of the primary producers of the input, the final consumers of the product as well as the competition policy directed towards the food industry (McCorriston, 2002).

4. Conclusions

The objective of this study is to demonstrate that the recently developed SFA estimator of market power measures more than just the mark–up in the output market as shown by the original work of Kumbhakar et al. (2012). Starting from the basic inequality $P > MC$ of Kumbhakar et. al.'s (2012) model, the present work demonstrates that the SFA estimator accounts for both the mark–up in the output market and the mark–down in the related primary input market. The SFA estimator measures the mark–up in the output market only under a specific market structure. Without having tested in advance for the presence of market power in the output as well as in the primary input market, it is only safe to say that the SFA estimation technique captures both oligopolistic and oligopsonistic distortions. Any other interpretation can lead to biased predictions regarding the source of market power in the relevant market.

Given the importance of the food industry to the economy and the vast interest of anti-trust authorities in preventing non-competitive behavior in the food industries, the measurement of market power will continue to be revisited in the food economics literature and be a major issue for economists as well as policy makers.

One of the biggest challenges for future research is to develop a theoretical model where the oligopolistic and oligopsonistic distortions can be disentangled from each other and uniquely measured by the SFA estimator of market power. This would enable the researcher to test for market power in the output and the input market separately. Statistically significant estimates for $u_i^{oligopoly}$ and $u_i^{oligopsony}$ would indicate the presence (or not) of market power in the output and/or in the input markets respectively. Among other things, certain assumptions for the distribution of the terms $u_i^{oligopoly}$ and $u_i^{oligopsony}$ would be required.

Notes

[1]This work borrows terminology from Azzam and Andersson (2008).

[2]One can identify the similarities of Kumbhakar et. al.'s (2012) model to this study: the sawlogs correspond to the primary farm input, transformation of the sawlogs to the processed output can be considered of fixed proportions, and the processing costs are equivalent to the variable costs that the seminal article employs.

[3]The processing cost function assumes the translog form like Kumbhakar et. al.'s (2012) model.

[4]The slope of the marginal cost for the upstream perfectly competitive industry is positive.

[5] According to Kumbhakar et al. (2012), the stochastic version of the profit maximizing relationship for the i^{th} firm is:

$$\frac{P\,q_i}{C_i} = h(q_i, w, f, \tau) + u_i + e_i$$

The equation above can be estimated with the use of the maximum likelihood method. The maximum likelihood method is based on the distributional assumption of the errors. The composed error term $(u_i + e_i)$ is no different than the one from a stochastic cost frontier model. The distributional assumptions regarding the terms u_i and e_i are: u_i is a normal variable truncated at zero from below, i.e. $u_i \sim N^+(0, \sigma^2_{u_i})$, and e_i is the usual two-sided normal noise term, i.e. $e_i \sim N(0, \sigma^2_{e_i})$. Hence, unlike the stochastic frontier analysis approach, u_i does not measure inefficiency in production. Instead, it measures inefficiencies due to the firm's anti-competitive behavior.

[6] In figure 1 we have dropped the subscript i.

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