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Estimating oligopsony power on two vertically integrated markets

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Abstract

The paper develops a new approach for the estimation of oligopsony power on two vertically integrated markets. The two subsequent markets with oligopsony power are structurally modelled. Deduced price equations are embedded in a VECM, transformed and estimated via the Kalman-Filter to allow for time-variation in the cointegration parameters. A dynamic factor model extracts common factors from the time-varying coefficients and thereby allows identification of buyers' market power on both markets. The framework is applied to the German dairy supply chain. Results indicate lower levels of market imperfections on the raw milk and higher levels on the dairy output market.

Keywords: Dairy, Industrial Organization, Market Power, Supply Chain.

1 Introduction

The study of buyers' market power has a long tradition in the new empirical industrial organization (NEIO) literature. The first to address the possibility of buyer's market power was Schroeter (1988). The oligopsonistic threat is a common issue on agricultural markets due to the atomicity of agricultural production on the supply side and a concentrated food industry due to significant scale economies on the demand side (Durham & Sexton, 1992). By assuming fixed proportions technology, Schroeter (1988) was able to estimate in his seminal work one measure for processors' market power which has the same magnitude on the material input and output market on the U.S. beef industry. The fixed proportion assumption was found to be very restrictive (i.e. Wohlgenant, 1989) and was relaxed by the later works of Azzam and Pagoulatos (1990) and Murray (1995). However, these approaches required quantity data on all inputs, which is frequently not publicly available. Muth and Wohlgenant (1999) were able to lower the data requirement in their approach. By implying that the non-material inputs enter the production process at their optimal quantities conditional on the material input level, only the prices of the non-material inputs are required for estimation of the structural model.

Until today, most empirical applications of NEIO oligopsony studies have focused on agricultural markets and in particular on the relationship between farmers and processors (e.g. Hockmann & Vönecki, 2009; Perekhozhuk et al., 2013; Scalco & Braga, 2014; etc.). However, since the 1990s, mergers and acquisition activities have heavily promoted concertation at the retail level in the EU and the USA. By mid-1990 retail concentration in the EU surpassed the food sector's concentration level, and is today much higher than the concentration in the food processing industry has ever been (Swinnen & Vandeplas, 2010). These rather new developments at the retail level seemed to have reshaped the nature of agri-food supply chains. Apart from the concentration processes at this stage, retailers have frequently integrated wholesaling into their business, thus extinguishing this stage, and further taken control over the upstream stages by demanding specific products and creating own brands (Dobson et al., 2003).

Public awareness on the buyer power of retailers was ultimately heightened in the year 2009. While consumer food prices and agricultural producer prices experienced a similar trend of rapid growth over the years 2007 and 2008, producer prices quickly dropped below the pre-2007 level in 2009 but consumer prices remained high. As a result, the European Commission (EC) warned of negative long-term effects of the retailers' oligopsony power for the entire agri-food sector. The caused reduced profitability and quantity distortions could limit food processors' incentives to invest in

improved product quality and innovation of the production process and consequently lower the future efficiency and competitiveness of the entire chain (EC, 2009).

Nevertheless, research on oligopsonistic behaviour of retailers remains scarce. Only a few studies so far have factored in this development and the possible thread of retailers' buyer power on the food industry output market in their empirical applications (i.e. Falkowski, 2010; Gohin & Guyomard 2000; Lloyd et al., 2009; Madau et al., 2016). Just three studies exist, to the best of our knowledge, that estimated a measure of market power. These are the works of Gohin and Guyomard for the French, Anders (2008) for the German, and Salhofer et al. (2012) for the Austrian retail sector. The primary cause for this is the relative scarcity of data. Even though, data at the producer and consumer level are frequently publicly available, the terms between retailers and food processors remain mostly hidden (Lloyd et al., 2009; Sexton, 2013).

The aim of the following work is to overcome this deficit and add to the literature. However, in contrast to the before mentioned studies on oligopsony power by retailers, also oligopsony behaviour of food processors towards farmers is considered to approximate the structure of modern agri-food supply chains as accurate as possible. In addition, the data prerequisite is significantly lowered by deriving a model that does not require any kind of quantity data, but requires only data on prices, for outputs and inputs along an agri-food supply chain. While the 'first-pass' test of Lloyd et al. (2009) also only requires price data, no actual measure of market power can be derived. To the best of our knowledge we are not aware of any similar approach in the economic literature so far that is able to derive a measure of oligopsony power without using any form of quantity data.

For empirical application the German dairy supply chain was selected due to the following characteristics, which make it a primary target for the study of subsequent oligopsony along an agri-food supply chain. The retail sector is dominated by a handful of firms which generate the major share of food retailing revenue. These retailers face around a hundred dairy companies on the markets for dairy products. Nevertheless, also the dairy stage can be considered as highly concentrated with up to 50% of German raw milk processed by only five companies (Loy et al., 2015). German dairies, on the other hand, source raw milk almost entirely from a domestic and atomistic primary production consisting of ten thousands of dairy farmers. Not surprisingly, the German anti-trust agency has recently investigated the sector for market power abuse. However, in their final report of the year 2012 the German anti-trust agency was only able to state that procurement prices are low and the structure along the chain seems to favour the position of buyers on both markets rather than to provide any evidence on the actual abuse of market power (Bundeskartellamt, 2009; 2012).

2 Theoretical model

Our model extends the approach of Muth and Wohlgenant (1999) with a sequential downstream market also characterized by oligopsonistic behaviour. To limit the complexity of the structural model of the two markets and assure empirical applicability, a series of assumptions has to be drawn initially. We start by assuming that the material input and output are each homogenous products. Furthermore, no stockpiling along the chain exists and imports as well as exports are ignored. With the exclusion of imports and exports as well as of stocks, the quantity of output cannot exceed the material input quantity produced in the same time period t .

Moreover, no agent involved in the transformation of the product from material input to marketed output faces any form of adjustment costs. Consequently, the market power measure of the later derived model is 'static' (Perloff et al., 2007). To avoid any limiting assumptions on the technology, second order-differential quadratic forms are used for any cost, production, or revenue function stated in the following sections (Chambers, 1988). The quadratic form allows approximating the true technology without a prior knowledge, and does not set any restrictions on "homotheticity,

homogeneity or the elasticities of substitution between factors” (Gollop & Roberts, 1979: 318). Furthermore, flexible functional forms also provide the necessary non-linearity to derive the market power measure as well as avoid multicollinearity issues (Bresnahan, 1989; Perloff & Shen, 2012).

Because we defined both products, the material input and output, as homogenous, the strategic variables are quantities (Sexton, 2000). With the previous stated restrictions in mind, we assume that the processing industry consist of n firms exclusively sourcing their material input on the domestic material input market and selling their output to m retailers on the domestic output market. Given the cost function of farmers and the assumption that farms are price takers on the material input market, due to their atomicity and thus low bargaining power, we can derive the inverse supply function of material input, since their marginal costs equal the farm gate price for the material input W^M ,

$$W^M = \frac{\partial C(X^M, W_h^F, T^F)}{\partial X^M} = S^{M-1}(X^M, W_h^F, T^F) = \rho^X + \sum_{i=1}^h \rho_i^{NX} W_i^F + \rho^{TX} T^F + \rho^{XX} X^M \quad (1)$$

where W_h^F is a vector of prices of h non-material inputs involved in the production of the aggregated farm output X^M , T^F is a trend variable depicting technical change at the farm level, and ρ s are parameters to be estimated. Given this supply relation we can formulate processor i 's profits as

$$\pi_i^P = r_i^P(P, x_i^M, x_{ki}^{P*}, T^P) - W^M x_i^M - W_{ki}^P x_{ki}^{P*} \quad (2)$$

where P demarks the output price, $r_i^P(\bullet)$ is the revenue function of the i^{th} processor, $x_{ki}^{P*} = x_{ki}^P(x_i^M, P, W_{ki}^P)$ is a vector of k non-material inputs used in the production of the output at their optimal quantity conditional on processor i 's choice of material input x_i^M , W_{ki}^P a vector of the corresponding prices of the k non-material inputs, and T^P captures technological change at the processing level. The first-order condition with respect to the choice of x_i^M yields:

$$\frac{\partial \pi_i^P}{\partial x_i^M} = \frac{\partial r_i^P(\bullet)}{\partial x_i^M} + \left(\frac{\partial r_i^P(\bullet)}{\partial x_{ki}^{P*}} - W_{ki}^P \right) \frac{\partial x_{ki}^{P*}}{\partial x_i^M} - W^M - \theta_i^P \frac{S^{M-1}(\bullet)}{\partial x_i^M} x_i^M = 0 \quad (3)$$

where $\theta_i^P = \partial X^M / \partial x_i^M$ is the i th firm's conjectural variation (CV). Under the assumption of procurement of the non-material inputs x_{ki}^P in competitive input markets and aggregating across firms by averaging over all dairies' marginal product (3) can be reduced and rearranged to yield:

$$\underbrace{W^M \left(1 + \frac{\Xi^P}{\eta^F} \right)}_{\text{'perceived' MFC}} = \underbrace{\frac{\partial R^P(P, X^M, X_k^P(X^M, P, W_k^P), T^P)}{\partial X^M}}_{MRP} = \varphi^X + \varphi^{PX} P + \varphi^{XX} X^M + \sum_{j=1}^k \varphi_j^{XN} W_j^P + \varphi^{XT} T^P \quad (4)$$

where the observed material input price plus a relative mark-down Ξ^P / η^F is the ‘perceived’ MFC, which equals its marginal revenue of product (MRP), where $\Xi^P = \sum (\partial X^M / \partial x_i^M) (x_i^M / X^M)$, $\eta^F = (\partial S^M(\bullet) / \partial W^M) (W^M / X^M)$ is the elasticity of material input supply, and φ s are parameters to be estimated. In the case of perfect competition on the output market $MRP = \text{Value of marginal product (VMP)}$. Ξ^P can be either interpreted as the average industry's conjectural elasticity, which measures the response in total industry input quantity to a change in the i^{th} processor's input level, or as the wedge between the material input price and its MRP. In general, it can be seen as an index which represents the processing industry's ability to mark-down the price of the material input given η^F (Sperling, 2002). The conjectural variations approach, the so-called “conduct parameter method” (CPM) (Corts, 1999), has been criticized on various levels and its suitability for empirical application has been questioned. The primary critic of the CPM is that the dynamic that underlie firms' conjectures on the rivals' response to quantity changes cannot be estimated with a static model (Friedmann, 1983; Corts, 1999). Consequently, even though the methodology developed in the later parts of this paper will not involve static but rather ‘dynamic estimation’, we restrain from the idea from estimating conjectures of firms but rather an index of market power (MPI). The range

of the index is zero to one. While zero signals perfect competition, one stands for monopsony. Values in between the extremes represent some level of oligopsony with $1/n$ as the Cournot outcome (Bresnahan, 1989).

The downstream market for the output product is modelled in a similar fashion as the upstream material input market model, but using Morrison Paul's (2001) cost side approach to the oligopsony model. The supply function S^Q of the output Q is derived by applying Hotelling's Lemma (Hotelling, 1932),

$$\frac{\partial \Pi^{P^*}(P, W^M, W_k^P, T^P)}{\partial P} = Q = \varphi^{PP}P + \varphi^P + \varphi^{PX}X^M + \sum_{j=1}^k \varphi_j^{PN}W_j^P + \varphi^{PT}T^P \quad (5)$$

where Π^{P^*} is the total processing industry's input optimized profit function¹. Given the supply of the output product (5), the j^{th} retailer's demand can be derived. Profit maximization behaviour implies that j^{th} retailer's cost function differentiated with respect to the choice of output product level as a material input as well as keeping the quantities of the l non-material inputs used in the marketing process again at their optimal quantity $q_{lj}^{R*} = q_{lj}^R(q_j, P, W_{lj}^R)$ conditional on the j^{th} retailer's chosen input level of the processing industry's output q_j , yields

$$\underbrace{\frac{\partial c_j^R(q_j, P, q_{lj}^R(q_j, P, W_{lj}^R), W_{lj}^R, T^R)}{\partial q_j}}_{\text{perceived' MFC}} - \theta_i^R \frac{\partial S^{Q^{-1}}}{\partial q_j} q_j = \underbrace{P}_{VMP} \quad (6)$$

where the 'perceived' MFC of the output product equals the output price P . $\theta_i^R = \partial Q / \partial q_j$ represents retailer j 's CV, W_{lj}^R is a price vector for l non-material inputs required for marketing, and T^R stands for the technological change at the retail level. After aggregating across all retailers' cost functions by using a Gorman polar form, which allows firms to have individual, but parallel cost functions and thus marginal cost must equal across all firms (Sperling, 2002), retailers' marginal costs can be formulated as

$$\frac{\partial C^R(Q, P, q_i^R(Q, P, W_i^R), W_i^R, T^R)}{\partial Q} = P \left(1 + \frac{\Xi^R}{\eta^P} \right) = \vartheta^Q + \vartheta^{QQ}Q + \sum_{k=1}^l \vartheta_k^{NQ}W_k^R + \vartheta^{TQ}T^R \quad (7)$$

where the MFC equal the output price plus a relative mark-down Ξ^R / η^P and ϑ s are parameters to be estimated. Consequently, as on the material input market, $\Xi^R = \sum(\partial Q / \partial q_j)(q_j / Q)$ is the ability to mark-down the price of the processing industry's output given the supply elasticity of the output $\eta^F = (\partial S^Q(\bullet) / \partial P)(P / Q)$. Interpretation is accordingly to Ξ^P .

Due to the assumption that all non-material inputs used along the supply chain to transform the product are procured on competitive markets, the respective prices and quantities are exogenous and only the material input and output quantities X^M and Q as well as the individual prices W^M and P remain as endogenous variables. The equations (1), (4), (5), and (7) are the supply and demand relations respectively for the material input and output market which incorporate the possibility of oligopsonistic behaviour and determine the equilibrium outcome on both markets. The system is very similar to the model of Muth and Wohlgenant (1999), but includes oligopsony power on the output market, and would still require data on material input and output quantity. However, after rearrangement and substitution similar to Lloyd et al. (2009), it is possible to determine the simultaneous partial market equilibria and the explicit solutions for the endogenous variables,

$$X^M = -\frac{1}{\varphi^{PX}} \left(B - \frac{\varphi^{PPE}}{\Xi_t^R - \varphi^{PP}\vartheta^{QQ}} + G \right) \quad (8)$$

$$W^M = \sum_{i=1}^h \rho_i^{NX} W_i^F + \rho^{TX} T^F + \sum_{j=1}^k \varphi_j^{PN} W_j^P - \frac{\rho^{XX}}{\varphi^{PX}} \left(B - \frac{\varphi^{PPE}}{\Xi_t^R - \varphi^{PP}\vartheta^{QQ}} + G \right) \quad (9)$$

¹ $\Pi^{P^*}(P, W^M, W_k^P, T^P) = R^P(P, x_i^{M^*}, x_{ki}^{P^*}, T^P) - W^M x_i^{M^*} - W_{ki}^P x_{ki}^{P^*}$

$$Q = -\frac{A+BZ+(Z\varphi^{PP}+\varphi^{PX^2})E}{\varphi^{PPD}} \quad (10)$$

$$P = -\frac{(A+BZ)\left(-\frac{\Xi_t^R}{\varphi^{PP}}+\vartheta^{QQ}\right)+EZ}{\varphi^{PPD}} \quad (11)$$

where $A = \varphi^{PX}\left(-\sum_{i=1}^h \rho_i^{NX}W_i^F - \rho^{TX}T^F + \varphi^X + \sum_{j=1}^k \varphi_j^{XN}(W_j^P - 1) + \varphi^{XT}T^P\right)$, $B = \varphi^P + \sum_{j=1}^k \varphi_j^{PN}W_j^P + \varphi^{PT}T^P$, $E = \vartheta^Q + \sum_{k=1}^m \vartheta_k^{NQ}W_k^R + \vartheta^{TQ}T^R$, $D = \frac{-Z}{\varphi^{PP}} + \left(Z + \frac{\varphi^{PX^2}}{\varphi^{PP}}\right)\left(-\frac{\Xi_t^R}{\varphi^{PP}} + \vartheta^{QQ}\right)$, $G = \frac{(-1-\Xi_t^R+\varphi^{PP}\vartheta^{QQ})\left((A+BZ)\left(-\frac{\Xi_t^R}{\varphi^{PP}}+\vartheta^{QQ}\right)+EZ\right)}{(\Xi_t^R-\varphi^{PP}\vartheta^{QQ})D}$, and $Z = (1 + \Xi_t^P)\rho^{XX} - \varphi^{XX}$. The equations of the endogenous variables solely depend on exogenous variables, the prices of non-material inputs, time trends that depict the technology change at each stage, and the measures for oligopsony power on the respective markets Ξ^P and Ξ^R .

Solving the explicit solution of P (11) once for one of the non-material input prices at the processing level W_h^F and once at the retail level W_l^R as well as substituting these solutions into the explicit solution for W^M permits to derive two pricing equations, denoted in the rest of the paper as farm-processor equation (FPE), from which all the retail level specific variables W_l^R and T^R are excluded, and as processor-retailer equation (PRE), from which the farm specific variables W_h^F and T^F are omitted (for details see in the empirical section (18) and (20)). For reasons that will become obvious in the empirical application section, the FPE is rearranged and solved for the price of non-material inputs at the farm level W_h^F and the PRE is similarly solved for the prices of non-material inputs at the retail level W_l^R . To simplify the notation, only one non-material input per stage is represented and the trends depicting technological change at each individual stage are merged to one time trend T . Thus, the FPE (12) and the PRE (13) take the form,

$$\text{Farm-processor equation: } W^F = \beta_1^C + \beta_1^{W^M}W^M + \beta_1^P P + \beta_1^{W^P}W^P + \beta_1^T T \quad (12)$$

$$\text{Processor-retailer equation: } W^R = \beta_2^C + \beta_2^{W^M}W^{M*}\Omega + \beta_2^P P + \beta_2^{W^P}W^P + \beta_2^T T \quad (13)$$

where the β s and Ω are parameters containing the parameters of the supply and demand relations as well as the oligopsony power measures Ξ^P and Ξ^R . W^{M*} is a transformed variable obtainable after knowledge on the parameter estimates of the FPE². Simply estimating (12) and (13) would not permit to identify Ξ^P and Ξ^R since they are elements of the β s. Nevertheless, if identification was possible through standard estimation techniques, these would only yield constant estimates of the market power measures what does not accommodate firms' behaviour of adaptive expectations (Gollop & Roberts, 1979). The empirical methodology that allows identification through the FPE and PRE and results in an adaptive measures of market power will be presented in the next section.

3 Empirical model

The two deduced equations solely involve price variables. Before further proceeding it has to be acknowledged that price time series, in particular of prices of vertically or horizontally integrated markets, are frequently non-stationary due to a common trend. Ignoring the possibility of non-stationarity might result in auto-correlation and thus biased estimates. Error correction techniques have been established to avoid spurious regression results (Hendry & Doornik, 2001; Juselius, 2006). The original ECM of Engle and Granger (1987) only accounted for one long-run equilibrium relation. Johansen (1988; 1991) developed the vector error correction model (VECM), which

² $W^{M*} = W^M - \varphi^{PX}P - \sum_{j=1}^k \varphi_j^{XN}W_j^P - \varphi^{XT}T - \varphi^X$

permits estimating a system of n cointegrated time series with $n-1$ cointegration vectors via maximum likelihood (ML). The VECM representation of Johansen (1988; 1991) is the following,

$$\Delta Y_t = \alpha \beta' Y_{t-1} + \sum_{i=1}^{p-1} \Gamma_i \Delta Y_{t-i} + u_t \quad (14)$$

where Y_t is the data vector of the n variables, Δ is the difference operator, Γ_i ($n \times n$) is a parameter matrices quantifying the short-run response of ΔY_t to past shocks, t is a subscript indicating the time dimension, and p is the number of lags. Furthermore, β is the cointegration matrix ($r \times n$) that quantifies the long-run equilibrium relationship with r , the so-called ‘rank’, being the number of cointegration relationships among the n time series. The α matrix ($n \times r$) is the so-called loading matrix, which measures the speed by which the system moves back to the equilibrium after deviations, given by $\beta' Y_{t-1} = ECT_{t-1}$, with regard to t . The error term u_t is a ($n \times n$) matrix of normal and identical distributed disturbances with zero mean and non-diagonal covariance matrix (Johansen, 1988; 1991; Juselius, 2006; Lloyd et al., 2009).

To simplify the estimation of a VECM Lütkepohl and Krätzig (2004) developed the simple two step (S2S) estimation procedure. By applying the Frisch-Waugh-Lovell Theorem (Lovell, 2008) in their procedure (14) can be reduced to,

$$M \Delta Y_t = \alpha \beta' M Y_{t-1} + u_t \quad (15)$$

where $M = I - \Delta Y_{t-1} (\Delta Y_{t-1}' \Delta Y_{t-1})^{-1} \Delta Y_{t-1}'$ transforms the variables Y_t and Y_{t-1} so that they incorporate the partial effect of the short-run dynamics. In the next step of the S2S, (15) is estimated via simple OLS, and a parameter matrix $\gamma = \alpha \beta'$ ($n \times n$) is obtained. By normalizing the cointegration vector β , setting the value of the corresponding β s of r variables to one and zero otherwise, the α matrix is identified. Furthermore, it is important to note that the choice of normalization does not affect the estimates of a cointegration relationship (Juselius, 2006). With knowledge of the loading matrix α , (15) is rearranged to yield,

$$M W_t = \beta' M Y_{t-1}^2 + v_t \quad (16)$$

where $W_t = (\alpha' \Sigma_u^{-1} \alpha)^{-1} \alpha' \Sigma_u^{-1} (\Delta Y_t - \alpha Y_{t-1}')$ is a r scaled vector, Σ_u being the residual covariance matrix of the error term u_t and $Y_{t-1} = (Y_{t-1}^1, Y_{t-1}^2)$ is split into Y_{t-1}^1 , the r time series whose cointegration parameters were normalized, and Y_{t-1}^2 , the remaining data vector (Lütkepohl & Krätzig, 2004). Even though, the S2S approach uses OLS for estimation, its estimator has the asymptotic distribution of a maximum likelihood estimator (Ahn & Reinsel, 1990; Reinsel, 1993).

In the case of the previous developed structural model with two pricing equations, two cointegration relationships are required. Thus, the vector W_t would consist of two elements. After the identification of α , W_t can be calculated and illustrated in the matrix notation in the following way,

$$\begin{pmatrix} W_t^1 \\ W_t^2 \end{pmatrix} = (\alpha' \Sigma_u^{-1} \alpha)^{-1} \alpha' \Sigma_u^{-1} \left(\Delta Y_t - \begin{pmatrix} \alpha_{W^F} \\ \alpha_{W^R} \end{pmatrix} \left(W_1^F + \sum_{i=2}^h \underbrace{\frac{\rho_i^{NX}}{\rho_1^{NX}}}_{\beta_1^{W_i^F}} W_i^F \quad W_1^R + \sum_{k=2}^m \underbrace{\frac{\vartheta_k^{NQ}}{\vartheta_1^{NQ}}}_{\beta_2^{W_k^R}} W_k^R \right) \right) \quad (17)$$

Instead of using standard OLS techniques, as suggested by Lütkepohl and Krätzig (2004), the Kalman-Filter (Kalman, 1960) is applied to the transformed VECM (16). This procedure generates time-varying estimates of the β s. This time-variation is caused by firms’ behaviour of adaptive expectations and updating Ξ^P_t and Ξ^R_t at each point in time t . All other parameters of the supply and demand relations are constant over time.

The state-space representation of the FPE and PRE are given by equations (18-21). However, prior to applying the Kalman-Filter the FPE has to be rearranged in the form that the dairy output P is the

dependent variable, since otherwise identification of Ξ^P_t is not unique. As mentioned before, this does not affect the estimates of a cointegration relationship (Juselius, 2006).

$$\text{FPE: } W_t^{1*} M = \underbrace{\left(\frac{\omega_0^{W^M}}{\left(\frac{1}{\varphi^{PX}} - \frac{\varphi^{XX}}{\varphi^{PX}\rho^{XX}} \right)} + \Lambda_t^P \right)}_{\beta_{1t}^{W^M}} W^M M + \sum_{i=1}^h \underbrace{\left(\frac{\omega_i^{W^F}}{\left(\frac{\rho_i^{NX}\varphi^{XX}}{\varphi^{PX}\rho^{XX}} \right)} + \overbrace{(-\rho_i^{NX})}^{\omega_1^{W^F}} \Lambda_t^P \right)}_{\beta_{1t}^{W^F}} W_i^F M +$$

$$\underbrace{\left(\frac{\omega_0^T}{\left(\frac{\rho^{TX}\varphi^{XX}}{\varphi^{PX}\rho^{XX}} - \frac{\varphi^{XT}}{\varphi^{PX}} \right)} + \overbrace{(-\rho^{TX})}^{\omega_1^T} \Lambda_t^P \right)}_{\beta_{1t}^T} T M + \underbrace{\left(\frac{\omega_0^C}{\left(\frac{\rho^X\varphi^{XX}}{\varphi^{PX}\rho^{XX}} - \frac{\varphi^X}{\varphi^{PX}} \right)} + \overbrace{(-\rho^X)}^{\omega_1^C} \Lambda_t^P \right)}_{\beta_{1t}^C} M + v_{1t} \quad (18)$$

$$\beta'_{1t+1} = \beta'_{1t} + \varsigma_{1t}' \quad (19)$$

$$\text{where } \Lambda_t^P = \frac{\Xi_t^P}{\varphi^{PX}} \text{ and } W_t^{1*} M = \frac{W_t^1 + W_1^F + \sum_{i=2}^h \frac{\rho_i^{NX}}{\rho_1^{NX}} W_i^F - \beta_{1t}^P P - \sum_{j=1}^k \frac{-\varphi_j^{XN}}{\varphi^{PX}} W_j^P}{\beta_{1t}^P} M.$$

$$\text{PRE: } W_t^2 M = \underbrace{\left(\frac{\tau_0^{W^M}}{\left(\frac{\vartheta^{QQ}}{\vartheta_1^{NQ}\rho^{XX}} \right)} + \frac{\tau_1^{W^M}}{\rho^{XX}} \Lambda_t^R \right)}_{\beta_{2t}^{W^M}} \left[\Omega_t^P \left(W^M - \frac{\tau_2^P}{\varphi^{PX}} P - \sum_{j=1}^k \frac{\tau_2^{W^P}}{\varphi_j^{XN}} W_j^P - \frac{\tau_2^T}{\varphi^{XT}} T - \frac{\tau_2^C}{\varphi^X} \right) \right] -$$

$$M + \underbrace{\left(\frac{\tau_0^P}{\left(\frac{1-\varphi^{PP}\vartheta^{QQ}}{\vartheta_1^{NQ}} \right)} + \overbrace{(-\varphi^{PP})}^{\tau_1^P} \Lambda_t^R \right)}_{\beta_2^P} P M + \sum_{j=1}^k \underbrace{\left(\frac{\tau_0^{W^P}}{\left(\frac{-\varphi_j^{PN}\vartheta^{QQ}}{\vartheta_1^{NQ}} \right)} + \overbrace{(-\varphi_j^{PN})}^{\tau_1^{W^P}} \Lambda_t^R \right)}_{\beta_{2t}^{W^P}} W_j^P M +$$

$$\underbrace{\left(\frac{\tau_0^T}{\left(\frac{-\varphi^{PT}\vartheta^{QQ}-\vartheta^{TQ}}{\vartheta_1^{NQ}} \right)} + \overbrace{(-\varphi^{PT})}^{\tau_1^T} \Lambda_t^R \right)}_{\beta_{2t}^T} T M + \underbrace{\left(\frac{\tau_0^C}{\left(\frac{-\varphi^P\vartheta^{QQ}-\vartheta^Q}{\vartheta_1^{NQ}} \right)} + \overbrace{(-\varphi^P)}^{\tau_1^C} \Lambda_t^R \right)}_{\beta_{2t}^C} M + v_{2t} \quad (20)$$

$$\beta'_{2t+1} = \beta'_{2t} + \varsigma_{2t}' \quad (21)$$

$$\text{where } \Omega_t^P = \frac{\varphi^{PX}}{\left(\Xi_t^P - \frac{\varphi^{XX}}{\rho^{XX}} \right)} \text{ and } \Lambda_t^R = \frac{-\Xi_t^R}{\varphi^{PP}\vartheta_1^{NQ}}.$$

The equations (18) and (20) represent the observation equation and (19) and (21) the corresponding state equation. The error terms ς_t are normally and identically distributed disturbances. The Kalman-Filter is a recursive procedure in which the estimates of the unknown state, here the parameters β_t as well as the corresponding covariance matrix Σ_t , are estimated using the last

observed values. In each time period, with new observations on the observable data, here W_t , floating in, the estimates are continuously updated (Kalman, 1960). Even if the assumption of Gaussian error terms fails to be true, the ML estimates of β_t s are still the best linear unbiased estimates (Wildi, 2013).

The Kalman-Filter requires to be initialized by a set of chosen starting values at time t_0 . In this case, we use the OLS estimates, which are also used as the non-time-varying parameters to rearrange the FPE, as initially suggested by Lütkepohl and Krätzig (2004) for their S2S method, for β and Σ to initiate the Kalman-Filter. After obtaining the optimized ML values for the initial parameters β_0 and Σ_0 , the procedure is repeated (Wildi, 2013).

As the state-space representation illustrates the estimates of the time-varying cointegration parameters β_t can be further separated into constant, here ω s and τ s, and non-constant components, so-called common factors, here the Λ s, by applying dynamic factor analysis (DFA). The general idea of the DFA is that n univariate time series form a multivariate system of variables, here after referred to as ‘response variables’. This system responds to changes in m common factors, where $l \leq m < n$, instead of trends unique to each individual univariate time series (Zuur et al., 2003). The DFA with one common dynamic factor, here Λ_t^P or Λ_t^R , based on either Ξ_t^P and Ξ_t^R , for the response variables, here β_t s, can be formulated by,

$$\beta'_{1t} = \omega'_0 + \omega'_1 \Lambda_t^P + \varepsilon_{1t} \quad (22)$$

$$\Lambda_t^P = \kappa^P \Lambda_{t-1}^P + \xi_{1t}^P \quad (23)$$

$$\beta'_{2t} = \tau'_0 + \tau'_1 \Lambda_t^P + \varepsilon_{2t} \quad (24)$$

$$\Lambda_t^R = \kappa^R \Lambda_{t-1}^R + \xi_{2t}^R \quad (25)$$

where the κ s are weighing the effect of past values of the common trends Λ_{t-1} on their current values Λ_t . The error terms, here ε_t and ξ_t , are assumed to be normally distributed with zero mean (Zuur et al., 2003).

The state-space representation consisting of (22-25) is estimated with ML. Nevertheless, since the dynamic factors are unknown the log likelihood function cannot be optimized directly. Instead the expectation-maximization (EM) algorithm is applied, an iterative procedure that “successively maximizes the conditional expectation of the complete data likelihood function” (Zuur et al., 2003: 668). Hereby the ML estimates of so-called hyperparameters are obtained. These hyperparameters comprise the variances of the error terms, the parameter μ s and κ s, and the initial values of the dynamic factors and their variances at t_0 . After determining the ML values of the hyperparameters the dynamic factors and their variances are obtained with help of the Kalman-Filter (Shumway & Stoffer, 2000).

Furthermore, some of the parameters have to be restricted to find a unique solution (Harvey, 1989). In this approach the initial variance of each dynamic factor is chosen to be zero at t_0 . However, similar to the estimation of the time-varying parameters of the transformed VECM, an initial ML estimation provides the optimized starting values for the final estimation. The dynamic factor analysis is carried out by using the MARSS package in the software R (Holmes et al., 2012). The dynamic factor models for each of the two parameter vectors are estimated separately. The reason is that Ξ_t^P enters the PRE through Ω_t^P , and thus must be determined prior to estimating the dynamic factor that extracts the common trend depending solely on Ξ_t^R . After obtaining the results of the DFAs the time-varying market power indices for processors and retailers can be calculated in the following way,

$$\Xi_t^P = \frac{\Lambda_t^P}{\omega_0^{WM} - \frac{\omega_0}{\omega_1} \frac{W_t^F}{W_t^P}} \text{ and } \Xi_t^R = -\Lambda_t^R \frac{\tau_1^P}{\tau_0^P - \frac{\tau_0^{WM} \tau_1^P}{\tau_1^{WM}}} \quad (26)$$

where with information³ on η^F and η^P the Lerner indices, also Buyer Power Index (BPI) (Blair & Harrison, 1993), here called BPI^P and BPI^R could be calculated as well,

$$BPI^P = \frac{VMP^M - W^M}{W^M} = \frac{\varepsilon^P}{\eta^F} \text{ and } BPI^R = \frac{VMP^Q - P}{P} = \frac{\varepsilon^R}{\eta^P} \quad (27)$$

which provide the percentage mark-down due to oligopsony conduct and thus the effect of market power on the prices. Even though the pricing equations allow determining the percentage mark-down without the requirement for any kind of quantity data, it is not possible to derive the welfare loss and the rents at any level without information on quantity data.

4 Data

The German dairy supply chain was chosen because of its appropriateness for the developed model. Its structure, as reported by the German anti-trust agency, fits the structural model of two subsequent markets facing oligopsonistic behaviour. In addition, the chosen supply chain fulfils almost naturally most of the assumptions that had to be drawn.

Raw milk is a quite homogenous product, since it is an unprocessed and mainly undifferentiated product. The importance of a possible differentiated product, such as organically produced raw milk, remains marginal. Dairy products, on the other side, is a product category that comprises a vast majority of product subgroups, from cheese to milk powder, further distinguished in brand and standard products. Nevertheless, it has been argued that brand and standard dairy products as well as products of other differentiation can be seen as perfect substitutes within one dairy product subgroup, e.g. fat-reduced milk and standard milk, since no real quality difference seem to exist (Bundeskartellamt, 2009; Davis et al., 2009). Since products can be defined as perfect substitutes, at least the product groups can be stated to be homogenous products and a share-weighted price for dairy products can be calculated (Stigler, 1964).

The hypothesis of no significant imports and exports can be proven to be a good approximation of reality. While regarding raw milk this is done at ease, since German dairies sourced around 93.8% of raw milk domestically in 2015, for the dairy product market more elaboration is necessary. Around 72% of total dairies' revenue is generated domestically (MIV, 2016). Furthermore, large shares of the remaining 28% of German dairies' revenue are actually marketed internationally through German retailers. Unfortunately no data is available, but it has been stated by the German anti-trust agency that regarding milk for human consumption exports, two retailers market more than 50% of the export quantity (Bundeskartellamt, 2014). Furthermore, it was assumed that at no level of the dairy supply chain any form of stockpiling is conducted. Raw milk and dairy products, in particular the first one, are highly perishable products and have to be refrigerated to be stored over longer durations. Since this a costly form of storage, the effect of storage is assumed to be marginal and consequently negligible (Loy et al., 2016; Sckokai et al., 2013).

The time period for the study spans from January 2003 to December 2015 thus also covering major policy changes and events including the gradual and actual abolishment of the milk quota, EU enlargements, and intensive structural change at all levels of the supply chain, that have altered irrevocably the business environment and the structure of the German dairy supply chain.

$$\begin{aligned} \eta^F &= \frac{W^M}{\rho^{XX} X^M} = \frac{W^M}{W^M - \rho^X - \sum_{i=1}^h \rho_i^{NX} W_i^F - \rho^{TX} T^F}; \\ \eta^P &= \frac{\varphi^{PP} P}{Q} = \frac{\varphi^{PP} P}{\varphi^{PP} P + \varphi^P + \frac{\varphi^{PX}}{\rho^{XX}} (W^M - \rho^X - \sum_{i=1}^h \rho_i^{NX} W_i^F - \rho^{TX} T^F) + \sum_{j=1}^k \varphi_j^{PN} W_j^P + \varphi^{PT} T^P} \end{aligned}$$

The database includes all publicly available relevant material and non-material input costs for the production and marketing process along the dairy supply chain (see Table 1). The costs of capital and transport, here in form of the diesel price, are assumed to be a significant cost variable at all levels. Unfortunately, no data on actual capital costs were available, but it was approximated with the money market rates of the German federal bank. Raw milk is sourced on average by German dairies in a radius of 170 km. Consequently, transport costs play a major role in the procurement of raw milk. Furthermore dairy products are distributed throughout Germany, which again makes the inclusion for transport costs a necessary requirement for the analysis (Tribl & Salhofer, 2013).

Apart from capital and transportation costs, it is assumed further that the main cost in the production of raw milk is dairy cow feed. The procurement of feed sums up on average around 2/5 of the intermediate consumption in German agricultural production, specifically 40.5% in 2003 and 41.1% in 2014 (BMLE, 2016). The dairies main matter of expense is raw milk with a cost share of approximately more than 55% (Bundeskartellamt, 2012). In addition, labour and energy costs are treated as significant at the processing stage with cost shares of 6.2% (8.1%) and 2.1% (1.4%) respectively in 2014 (2003) (BMLE, 2016). Aside from the procurement price for dairy products, the main expense for the retail level is wages, e.g. accounting for up to 30% of the retail price in the case of U.S. retailers (Hovhannisyan & Gould, 2012).

Except for one data series, the frequency of the database was monthly. For the average wage of retail employees only data with quarterly frequency was available. Therefore, this time series was interpolated to a monthly frequency (see Table 1). All price time series were deflated using the Consumer Price Index (CPI) issued by the German federal statistic service.

Table 1: Descriptive statistics of used dataset

item	unit	frequency	symbol	min	max	mean	source
raw milk price	€/l	monthly	W^M	0.22	0.41	0.31	BMVEL/BMELV/BMEL
implied dairies' output price ^a	€/l	monthly	P	0.44	0.61	0.48	BMVEL/BMELV/BMEL
skim milk powder ^c	€/kg	monthly		1.39	3.63	2.13	BMVEL/BMELV/BMEL
German brand butter (formed) ^c	€/kg	monthly		2.17	4.44	3.24	BMVEL/BMELV/BMEL
Emmentaler ^c	€/kg	monthly		3.93	5.50	4.32	BMVEL/BMELV/BMEL
milk performance feed	€/kg	monthly	W^F	0.14	0.28	0.19	AMI/ZMP
avg. wage dairy industry ^b	€/h	monthly	W^P_1	15.25	28.11	21.77	BMVEL/BMELV/BMEL
energy price ^d	€/kWh	monthly	W^P_2	0.07	0.12	0.09	BMWE/Statistisches Bundesamt
avg. wage retail employee ^e	€/h	quarterly	W^R	9.87	13.13	11.53	Statistisches Bundesamt
money market rate ^f	%	monthly	W^{F+P+R}_1	-0.20	4.30	1.49	Deutsche Bundesbank
diesel price ^d	€/l	monthly	W^{F+P+R}_2	0.95	1.52	1.22	BMWE/Statistisches Bundesamt

Source: own elaboration.

Notes: ^a calculated using technical conversion factors and shares on processing; ^b seasonally adjusted using x12arima; ^c after March 2012 continued with index data, since price data was not published any further; ^d calculated using index series from Statistisches Bundesamt and avg. price of 2010 for energy procured by industry (0.0971 €/kWh) and diesel (1.23 €/l) provided by BMWE; ^e interpolated to monthly frequency using Eviews Software; ^f EONIA.

While data on the raw milk price is publicly available, the assumption of a homogenous dairy output product implies the construction of a corresponding price time series. The dairy output price P is consequently a share weighted price of major dairy products. It consists of the wholesale prices for Emmentaler, SMP, and German brand butter (formed)⁴.

⁴ The conversion rates for butter, SMP, and Emmentaler are 25 liter/kg, 10 liter/kg, and 7.5 liter/kg respectively.

5 Empirical results

The aforementioned methodology relies on cointegration relationships among the variables. The first step is to test for unit roots among the variables themselves. The Augmented Dickey-Fuller Test (Dickey & Fuller, 1981) results state that indeed all series have a unit root and are non-stationary. The next step is to test whether a combination of these exists that is stationary in the long-run and the time series accordingly cointegrated. The Saikkonen & Lütkepohl Test (Lütkepohl et al., 2004) for cointegration is applied to the system of eight data time series including a time trend and a constant in the possible long-run relationships⁵. Thus, the maximum rank, number of cointegration vectors, in this system is seven. The number of lagged differences suggested by the selection differs between Akaike Info Criterion (AIC), Final Prediction Error (FPEC), and Schwarz Criterion (SC). While SC suggests one and FPEC two lags, AIC prefers up to 12 lags. Nevertheless, for all three lag choices, the presence of at least two cointegration vectors cannot be rejected at the 10% significance level. With a lag length of 12, even more than five long-run relationships cannot be rejected statistically. Consequently, the previously described methodology, based on two cointegration vectors, is confirmed by the cointegration test results.

The Chow forecast compares the residual variance of the full sample with those of the first subsample. If these differ, the null hypothesis of constant residual covariance matrix and thus constant parameters has to be rejected (Lütkepohl & Krätzig, 2004). The test rejects the assumption of constant parameters and therefore confirms our assumption that the parameters are not constant over the entire period. Until around mid-2009 the hypothesis of constancy is rejected at the 5% level. However, the specification including 12 lags never rejects, except for one month at the end of the analysed time period, the null hypothesis, which might be caused by the relative small remaining sub period, which only ranges from November 2010 to November 2015, during which all other specifications also can not reject the stability of the system.

The VECM, in general, regards all variables of the database as endogenous. However, as assumed in the outlaid model, only the prices and quantities of the material input and the output are assumed to be endogenous. All other prices are treated as being exogenous. Setting linear restrictions on the loading matrix α as well as the parameter matrices that quantifies the short-run response of ΔY_t to shocks in the past, Γ_i allows to treat these variables as exogenous to the system. Restrictions are set by setting the corresponding parameters of these matrices to zero. When solely α is restricted, the variables, which are affected by the restriction, are treated as “weakly exogenous for the cointegrating parameters if none of the cointegration relations enter the equation for that variable” (Lütkepohl & Krätzig, 2004: 108). Further restricting the Γ_i as well limits the affected variables to be truly exogenous, not reacting to past developments of the endogenous variables or shocks to the system, and their presence in the VECM to the cointegration relationship. Consequently, these exogenous variables enter the VECM in a similar way as the deterministic components, the trend and the constant term.

The primary statistical analysis conducted and described in these previous paragraphs leads to a variety of model specification. The three criteria suggest three different lag lengths for the cointegration analysis. Consequently, one, two, and 12 differenced lags of the endogenous variables are incorporated in the different model specifications. The Saikkonen & Lütkepohl Test for cointegration revealed that in all cases, up to two cointegration vectors are accepted. The two cointegration vectors are normalized respectively on one of the non-material input prices at the farmers and retailers level. In addition, three different specifications of each model allowing either the non-material input price variables to be endogenous, weakly exogenous, or exogenous, are set. In total, nine different model specifications were estimated.

⁵ Due to the presence of a time trend and constant term in the structural price equations

From these nine specifications the model that best fits the data was chosen for further analysis. Apart from the pre-requirements of certain parameter significance and theoretical consistent values for Ξ^P_t and Ξ^R_t , the $\Delta AICc$ and, based on the $\Delta AICc$, the weighted AICc were used to identify the specification with best fit to the data. The model setup that describes the data with virtual certainty is a specification with two lags and weakly exogenous variables (see Table 2). The following presented estimations results are based on this setup.

Table 2: List of model specifications differing in lag length and the nature of the non-material input variables with their corresponding FPE results for AICc and the weighted AICc values.

no. of differenced lags	non-material input variable	required β_{1t} s significant	$0 \leq \Xi^P_t \leq 1$	required β_{2t} s significant	$0 \leq \Xi^R_t \leq 1$	$\Delta AICc$	weighted AICc
1	endogenous	yes	no	-	-	-	-
2	endogenous	yes	no	-	-	-	-
12	endogenous	yes	yes	yes	yes	2347.3	0%
1	weakly exogenous	no	-	-	-	-	-
2	weakly exogenous	yes	yes	yes	yes	0	100%
12	weakly exogenous	yes	no	-	-	-	-
1	exogenous	no	-	-	-	-	-
2	exogenous	yes	no	-	-	-	-
12	exogenous	no	-	-	-	-	-

Source: own elaboration, AICc values were obtained from the estimations within the MARSS package in R.

Table 3 presents the average values of the estimated time-varying cointegration parameters. In general, all parameters vary over time. While the average p-values of some parameters are above the 10%-significance level, e.g. for the time-varying parameter of the feed price in the FPE and of the trend in the PRE, these are very close to this statistical boundary, maximum 13.6%, and statistically significant at the 10%-level and below at certain points in time. Thus, they were included in the forthcoming dynamic factor analysis.

Table 3: Kalman-Filter results for the time-varying parameters of the FPE and PRE (average values) with corresponding standard errors (average values) and significance level.

parameter	value	standard error	parameter	value	standard error
$\beta_{1t}^{W^M}$	-1.2255***	0.1578	$\beta_{2t}^{W^{M^*}}$	-0.0966**	0.0355
$\beta_{1t}^{W^F}$	0.4711	0.2581	β_{2t}^P	31.1221***	4.1941
$\beta_{1t}^{W_1^{F+P+R}}$	0.1346**	0.0511	$\beta_{2t}^{W_1^P}$	1.2437***	0.2032
$\beta_{1t}^{W_2^{F+P+R}}$	-2.0700**	0.5740	$\beta_{2t}^{W_2^P}$	-207.125***	47.6628
β_{1t}^T	-0.0016***	0.0002	$\beta_{2t}^{W_1^{F+P+R}}$	4.4805**	1.1529
β_{1t}^C	-0.7363***	0.0517	$\beta_{2t}^{W_2^{F+P+R}}$	-51.9297**	17.7479
			β_{2t}^T	0.0174	0.0104
			β_{2t}^C	-52.6387***	7.5686

Source: own elaboration. Notes: ***Significance at the 1 per cent level **Significance at the 5 per cent level *Significance at the 10 per cent level

The results of the Kalman-Filter enter the DFA as dependent variables, whose purpose it is to extract from these a common factor that explains their variation over time. The common factor is a function of the market power indices and parameters of the derived supply and demand functions, and thus allows determining the level of market power abuse on each of the two analysed markets. The results of the DFA are illustrated in Table 4. All parameters necessary for the calculation of the market power indices as well as the average values of the common factors themselves are significant at the 1%-mark.

Table 4: DFA results for the constant parameters and dynamic factors (average values) with corresponding standard errors and significance level.

parameter	value	standard error	parameter	value	standard error
$\omega_0^{W^M}$	-1.1694***	0.0230	$\tau_0^{W^{M^*}}$	-0.1961***	0.0069
$\omega_0^{W^F}$	0.9326***	0.1779	τ_0^P	40.1471***	1.4883
$\omega_0^{W_1^{F+P+R}}$	-0.7486	0.5045	$\tau_0^{W_1^P}$	1.3810***	0.0219
$\omega_0^{W_2^{F+P+R}}$	-0.0271	0.0600	$\tau_0^{W_2^P}$	-118.0769***	7.5162
ω_0^T	-0.0014	0.0014	$\tau_0^{W_1^{F+P+R}}$	-31.1944***	3.7575
ω_0^C	-0.5403***	0.0811	$\tau_0^{W_2^{F+P+R}}$	5.6696***	0.3144
$\omega_1^{W^F}$	8.2354***	1.2335	τ_0^T	-0.0069**	0.0028
$\omega_1^{W_1^{F+P+R}}$	23.5763***	3.1322	τ_0^C	-79.7669***	2.3920
$\omega_1^{W_2^{F+P+R}}$	-2.8855***	0.6857	$\tau_1^{W^{M^*}}$	-0.0030***	0.0002
ω_1^T	0.0050	0.0297	τ_1^P	0.2693***	0.0405
ω_1^C	3.4974***	0.7199	$\tau_1^{W_1^P}$	0.0041***	0.0006
κ^P	1.0000***	0.0014	$\tau_1^{W_2^P}$	2.6570***	0.0456
Λ_t^P	-0.0560***	0.0006	$\tau_1^{W_1^{F+P+R}}$	0.6187***	0.1169
			$\tau_1^{W_2^{F+P+R}}$	0.0355***	0.00745
			τ_1^T	-0.0007***	0.0001
			τ_1^C	-0.8094***	0.0521
			κ^R	1.0000***	0.0015
			Λ_t^R	-33.5146***	0.4524

Source: own elaboration. Notes: ***Significance at the 1 per cent level **Significance at the 5 per cent level *Significance at the 10 per cent level

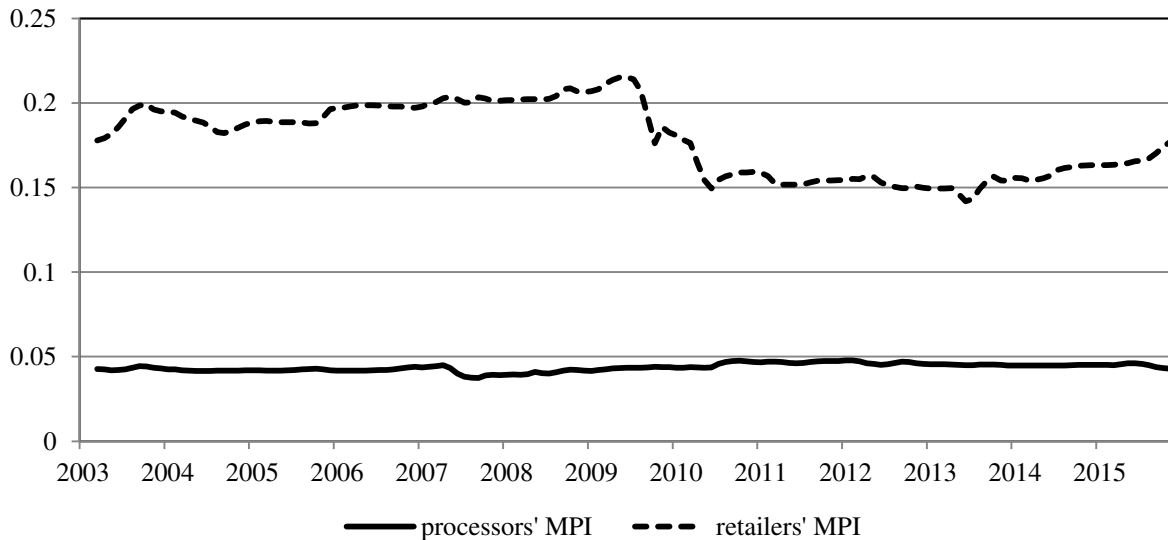


Figure 1: Calculated market power indices Ξ_t^P of dairies and Ξ_t^R of retailers.

Source: own elaboration.

Figure 1 displays the calculated market power level at the processing and at the retail stage and its evolution over the analysed time period. Table 2 already revealed that both market power indices lie in the theoretical consistent range from zero, perfect competition, to one, monopsony. The dairies' market power index Ξ_t^P fluctuates from 0.037 to 0.048 between the years 2003 and 2015. Starting with a value of around 0.042, the market power level reaches local maxima of around 0.044 at the end of 2003 and mid-2007. The last local maximum is quickly followed by a sudden drop to the absolute minimum of around 0.037 in the fall of 2007. Until the beginning of 2012 the time series is

characterized by a general increasing trend with the maximum value of about 0.048 at the end of this period. The last 36 months are coined with an overall decline in value.

The retailers' market power ranges from 0.14 to 0.22. While increasing steadily at the beginning of the analysed period from around 0.18 to its absolute maximum of 0.22 in the fall of the year 2009, $\bar{\varepsilon}_t^R$, drops drastically in value after the maximum to around 0.15 only a few months later in mid-2010. This drastic change splits the time sample in two distinct different time periods. From this date to around mid-2014 the market power index preserves around the value range 0.14 to 0.16. The last one and half years of the analysed timeframe the index starts to grow in value again and reaches its starting value of 0.18 again.

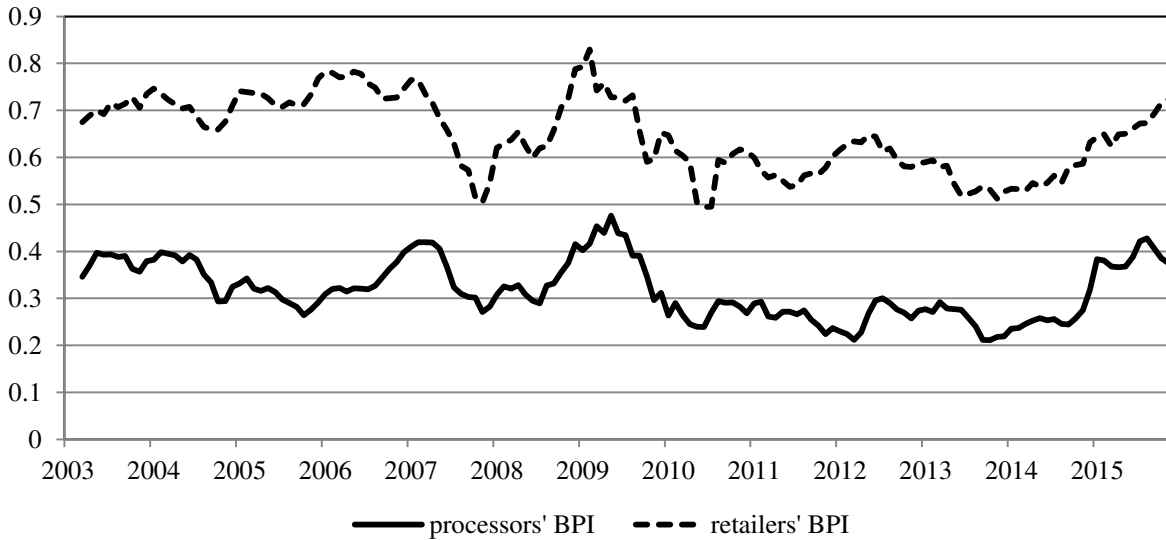


Figure 2: Calculated BPIs of dairies and of retailers.

Source: own elaboration.

Even though the market power of German dairies lies close to the perfect competition case with a value between 0.037 and 0.048, the BPI of dairies reaches values up to 0.48, in mid-2009, during the analysed period (see Figure 2), which is due to a relatively inelastic supply of raw milk with values between 0.09 and 0.22. The mark-down ranges from around 0.21 to 0.48 between 2003 and 2015. The evolution is rather erratic with large peaks at the beginning of the analysed period around summer 2004, mid-2007, mid-2009, and after the fall of 2013. While every peak is followed by a sudden drop in the BPI's value, the period from the beginning of 2010 to the fall of 2014 is characterized by rather low values in the range from 0.21 to 0.30. Similar to the dairies' BPI the retailers' BPI's value lies far above the value of the corresponding market power index $\bar{\varepsilon}_t^R$. The retailers' market power index's evolution in combination with relative inelastic dairy output supply with values ranging from 0.24 to 0.40 lead to a BPI with its minimum value of 0.49 and a maximum value of 0.82.

6 Discussion

Several factors would lead to the initial assumption of a rather high level of oligopsony level on the German raw milk market. German dairy farmers face a highly concentrated German dairy industry, in some regions more than 50% of the raw milk produced is sold to one firm (Bundeskartellamt, 2009) and almost no outside options exist. In addition, dairy farmers are confronted with the issue of a possible hold up through dairies due to the nature of raw milk production with its high asset specificity and the perishable nature of raw milk. The threat of a hold up and possible loss of output due to spoilage puts dairy farmers in a weak bargaining position with dairies (Grau et al., 2015).

Indeed, the market power index for dairies with its value range from 0.037 to 0.048 reveals market imperfections on the German raw milk market due to oligopsonistic conduct, but the level of oligopsony is rather low and close to perfect competition. Other studies on oligopsony conduct on raw milk markets report similar estimates. For example, Hockmann and Vönecki (2009) report a market power index of 0.05 for the Hungarian raw milk market, and Scalco and Braga (2013) for the Brazilian raw milk market of 0.01. Perekhozhuk et al. (2013) and Perekhozhuk et al. (2015) find higher level of oligopsony conduct on the Hungarian (0.22) and Ukrainian raw milk market (0.15), but still far from monopsony level.

A diverse number of reasons can explain the low level of oligopsony conduct on the German raw milk market. Even though the concentration of procurement reaches levels of more than 50% on regional markets, on a national aggregated level these might be local exceptions. Due to the usage of national aggregated price data the oligopsony conduct on regional German markets cannot be evaluated and no statement given. Furthermore, while six dairies summing up a market share of approximately 50% (Loy et al., 2015), around 70% of the German raw milk is processed through cooperatives. Dairy cooperatives are obliged to process all of the raw milk delivered by their members. Consequently, quantity reduction in procurement as a result of oligopsony power is not a feasible option and not in the interest of cooperatives. With cooperatives being dominant on the German raw milk market, the possible higher levels of market power through investor-owned dairies are counterbalanced (Tribl & Salhofer, 2013)

Even without the consideration of cooperative action, an actual hold up that can ruin dairy farmers is not likely to be enforced by dairies, since the benefits of a steady flow of raw milk to fully utilize capacities and therefore achieve cost-minimization production are greater (Schroeter & Azzam, 1991). Apart from the goal of cost-minimization, also dairies' investments in highly specific assets lower the incentive to use market power. The gain from higher profits in the short-run due to the application of market power is offset by lower rates of return on dairies' own investment, since the exertion of market power might force farmers to exit production and shrinks the procurement base and dairies' capability to utilize their capacities fully in the long-run (Crespi et al., 2012).

While the level of oligopsony is rather low throughout the investigated period, drastic relative changes can still be observed (see Figure 1). In particular, in the summer of 2007 the market power index of dairies punctiliously collapsed by about 18% in value. This might be a result of increased competition for raw milk between dairies due to growing export opportunities and high prices as a result of growth in global demand for dairy products, a production shock in New Zealand that drastically reduced supply on world markets, and low public stocks of dairy products in the EU (Acosta et al., 2014; Bouamra-Mechemache et al., 2008). The growth in the market power index after this period in turn might be a result of mergers and acquisitions boosting concentration at the dairy industry level as well as the growing raw milk supply as a consequence of the gradual abolishment of the quota, in particular since 2010. A growing supply base enhances collusive behaviour among buyers (Hockmann & Vönecki, 2009).

On the German dairy output market larger levels of market imperfections compared to the raw milk market can be observed. The market power index of retailers ranges over the analysed period from 0.14 to 0.22. Salhofer et al. (2012) find a similar level of market power on the Austrian butter procurement market by retailers with a market power index estimate of around 0.10. Even though, the German retail sector is highly concentrated, as the Austrian is, the level of market power is still far from monopsony or a collusive cartel. Again, the concept of capacity utilization and cost-minimization with the abundance of large storage facilities for dairy products (Loy et al., 2015) might explain the rather low market power index value in the presence of five German retailers accounting for more than 70% of revenues in German food retailing (BEV, 2016).

While the market power index value is far from monopsony level, the presence of significant oligopsony conduct on the dairy output market was still proven by the results. The German retail market, in particular for dairy products where consumers are very sensitive to price changes (Loy et al., 2016), is characterized by intensive horizontal price competition. Consequently, albeit five companies controlling German food retailing, it is unlikely for these to extract oligopoly margins due to intense competition for market shares. The exertion of oligopsony power might be an attempt of retailers to increase profits or market shares on highly competitive markets by offering lower prices secured by significantly marked-down procurement prices (Anders, 2008).

As with the market power index of dairies, drastic relative adjustment in the oligopsony conduct of retailers is apparent (see Figure 1). From 2003 to around mid-2009, the parameter's value increases from around 0.18 to 0.22. The continuing concentration process in form of mergers and acquisition at the retail level, the formation of procurement alliances among larger and smaller retailers, and the growing dairy output supply as a consequence of the gradual quota abolishment as well as cooperatives' commitment to process all their members' raw milk, might have enabled retailers to exert more market power on the dairy output market. However, after this period of growth in the market power index, it suddenly drops in one year, between mid-2009 to mid-2010, from its maximum value to its minimum value of 0.14. In the next three to four years the market power index remains on this level. However, in the summer of 2014 the index starts growing again steadily to finish off with its starting value of 0.18. A possible explanation for the sudden drop in value is that even though the number of retailers might have decreased over the time period, possibly a threshold was passed that made the buyers on the dairy output market procure more competitively (Sexton, 2013). The more recent increase of market power could be a result of growth in supply as a result of the growth in raw milk production, similar to the previously described situation on the raw milk market.

The exertion of market power on agricultural product markets is more dramatic than on other sectors' markets, since the inelastic supply magnifies the market power extend in form of a severe mark-down (Bakucs et al., 2010). The same can be said about the German raw milk and dairy output markets. Even though, the extent of oligopsony on both markets is rather low, in interaction with the corresponding inelastic price elasticity of supply, this leads to considerable mark-downs. The relative mark-down is expressed by the buyer power index.

On the raw milk market the BPI ranges from 0.21 to 0.48, meaning that the raw milk price was marked-down by oligopsony power in the range of 21% to 48% over the analysed period (See Figure 2). Unfortunately, no study has calculated a BPI for the raw milk market so far (for more details see Perekhozhuk et al., 2016), but studies on other agricultural products also report relative large relative mark-downs, up to 1.1 for livestock in the USA (Azzam & Pagoulatos, 1990), as a result of low levels of market power but inelastic supply (e.g. Azzam & Pagoulatos, 1990; O'Donnell et al., 2007; etc.).

With a larger extent of oligopsony power on the dairy output market in combination with a similar inelastic supply, the BPI of retailers achieves higher values in the range from 0.49 to 0.82 over the analysed period. While the literature provides at least BPIs for other agricultural markets, the only study that determined a BPI for the processor output market is Gohin and Guyomard (2000). These authors report a BPI of about 0.20 for dairy products, 0.17 for meat products and 0.12 for other food products. The two distinct time periods in the evolution of the retailers' market power index can also be observed in the BPI (see Figure 2). The drop in oligopsony power after 2010 drastically lowers the BPI of retailers to a value of around 0.49 to 0.60.

Overall, while oligopsony levels closer to perfect competition than monopsony were observed, the market imperfections in cooperation with the inelastic supply elasticity lead to drastically marked-down prices for raw milk and dairy output. As a consequence considerable amounts of rents were

shifted downstream along the German dairy supply chain. However, if these rents were passed on to consumers in form of low dairy products prices, which some studies (i.e. Loy et al., 2016) state is the daily practice of German retailers, in particular of discounters, institutions like the European Commission do not assess this as anticompetitive. In contrast, the German anti-trust agency holds the opinion that even if consumers benefit in form of low retail prices, it does not justify the use of market power (Bundeskartellamt, 2009). Because in this analysis the consumer market is not included, we have to agree with the view of the German anti-trust agency and characterize the German supply chain as anticompetitive. However, the abolishment of the milk quota boosting the elasticity of raw milk supply (Graubner et al., 2011), as well as the food retail market probably reaching a threshold level of concentration have benefited the competitiveness of the supply chain and lowered the relative mark-downs at each market.

The two markets of the German dairy supply chain are characterized by different levels of oligopsony behaviour. While dairy cooperatives seem to be able to counterbalance the oligopsonistic conduct of investor-owned firms and thus the raw milk market is close to perfect competition, the dairy output market approaches at times Cournot levels. Nevertheless, due to the rather inelastic supply of both products the market power indices lead to rather high mark-downs. In the economic literature a series of suggestions exist that might be feasible for the German dairy supply chain to lower these effects.

Procurement behaviour on the German raw milk market is fairly competitive. Actions to further counterbalance the market power of dairies, e.g. diversifying the homogenous product raw milk by switching to organic production, are only niche opportunities and will not greatly affect the entire market (Bundeskartellamt, 2009). Consequently, to lower the mark-downs, supply has to react more elastic to price changes (Hamilton & Sunding, 1997). A first step was already taken by abolishing entry barriers to the market in form of the milk quota, which as a result has likely increased the supply elasticity and lowered mark-downs (Graubner et al., 2011). Furthermore, other actions such as credit availability and technology transfer to dairy farmers as well as innovations at the farm level should be promoted since these allow raw milk production to respond more elastically (Atsbeha et al., 2016).

For the dairy output market, apart from the just mentioned supply elasticity enhancing policies, measures to lower the oligopsony conduct should be discussed. While cooperation among dairies might promote efficiency and the elasticity of supply, the German anti-trust agency is certain that further concentration at the dairy level will not increase their capability to achieve higher prices (Bundeskartellamt, 2009). One possibility to break the level of oligopsony is to increase the number of buyers for dairy products and thus the marketing options for dairies (Rude et al., 2011). One way to achieve this is to promote exports. However, the outcome of this approach might be rather restricted, since the quantities traded globally are growing but compared to the overall production still small. For example, the main competitor of European dairy products New Zealand only produces a raw milk quantity similar to the magnitude of the German federal state Bavaria (Bundeskartellamt, 2009). Another way is to increase the number of domestic buyers by dissolving procurement alliances between larger retailers and smaller retailers and further lifting regulations that are entry barriers to the German retail market (Perloff et al., 2007). One more possibility to counterbalance an oligopsony is to move from homogenous, generic products to heterogeneous products (Sutton, 1998). This is in particular true for dairy cooperatives which mainly produce standard products under store label brands and thus only achieve low prices for their dairy products (Loy et al., 2016). Though, the creation of higher value-added and more heterogeneous dairy products through the establishment of brands, product innovation, and labelling in form of geographic indications or production method should be promoted (Henson & Reardon, 2005).

7 Conclusions

In this paper a supply chain approach to estimate market power is developed. On the foundations of NEIO theory a structural model of two subsequent markets incorporating buyers' market power on the input as well as output market is established. After deriving the supply equations for the input and output good as well as the corresponding demand equations, a system of equations is formed that gives the explicit solutions for the endogenous variables. Rearranging the price equations permits to cancel quantity variables and estimate the model solely with price data.

For estimation, error correction representations of the two price equations are deduced, in which the long-run coefficients equal the parameters of the price equations. In contrast to standard error correction model assumptions and estimation procedures, we permit the long-run parameters to vary over time. The source of these variations is assumed to be due to changes in the buyers' market power conduct. Applying time series estimation techniques such as Kalman-Filter and dynamic factor analysis to the transformed VECM of the price equations allows extracting common time-varying factors, which are the foundation of the calculations of market power indices representing the oligopsony behaviour of processors and retailers respectively.

The developed model is applied to the German dairy supply chain over the period January 2003 to December 2015. The estimates of the market power indices for the dairy industry as well as retailing sectors reveal oligopsonistic market conduct. While the values of buyers' market power on the raw milk market are close to perfect competition, the prices on the dairy output market seem to be at times approaching the result of a Cournot outcome for five firms. This surprisingly fits the structure of German retailing, where the five largest food retailers summed up about 72.3% of market shares in grocery sales and through the establishment of procurement alliances with smaller retailers control almost completely food procurement and retailing in Germany (Bundeskartellamt, 2012; BVE, 2016).

In general, the results prove that the effect of market power on the prices of raw milk and dairy output are large. Even though, the levels of oligopsony power are closer to perfect competition than monopsony, the inelastic supply of raw milk and dairy output lead to large relative and absolute mark-downs, in particular on the German dairy output market. Because the consumer market is not part of the analysis, it is not clear whether retailers have passed on the lower prices for dairy products on to consumers. Without knowledge on this, the conclusion can only be that the market behaviour along the German dairy supply chain is anticompetitive and has lowered the overall welfare.

Even though this approach allowed identifying market power along the German dairy supply chain, a series of drawn assumption limit the explanatory power of this analysis. The negligence of adjustment costs and the exclusion of exports are likely to lead to an overestimation of the market power indices. However, these are common and necessary requirements in most market power studies (Sckokai, et al., 2013). Consequently, the values of the market power indices should be interpreted with care. The relaxation of these assumptions should be the focus of future research.

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