Artikel

A vector error-correction model of price time series for bottleneck detection in price coordination within a marketing channel

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Abstract

In this paper we propose a method for monitoring bottlenecks in price coordination within the marketing channel. First, a conceptual framework for price relationships in food marketing channels is developed. Then a vector error-correction model is proposed as a measurement instrument for monitoring price coordination in the food chain. An application to the marketing channel of pork in the Netherlands is provided. One of the conclusions is that if piglet prices show changes that cannot be explained by changes in pig, wholesale or retail prices, then breeders are not able to bring piglet prices back into line with the prices of the downstream stages in the chain without forcing the downstream stages to change their prices. This situation may hinder pork-chain members to conduct a joint consumer-driven marketing operation.

1. Introduction

This paper is concerned with bottlenecks in marketing channels of agricultural and food products. Bottlenecks in a marketing channel are defined as impediments at a particular stage of the marketing channel to adapt to changes in marketing variables, such as changes in customer wants and needs or changes in prices. Bottlenecks in the food marketing chain can result from shortcomings in market transparency and in the capacity or willingness of channel members to adapt to market changes.

Since we focus on adaptation to price changes, we consider bottlenecks that result from price coordination behaviour. This subject has been fundamentally discussed in the industrial economics theory (e.g. Tirole, 1988; Martin, 1993). The relationship between farm prices and consumer food prices has been extensively investigated in the vast literature on marketing margins (e.g. Berck and Rauser, 1982; Briz and De Felipe, 1997). This paper tackles a specific topic in this field. It tries to develop a method for monitoring the quality of price coordination in agricultural marketing channels. Such methods seem indispensable for spotting shortcomings in channel performance.

The paper is organized as follows: in Section 2 a conceptual framework for price relationships in food marketing channels is developed. In Section 3 vector error-correction modelling is proposed as a measurement instrument for monitoring price coordination in the food chain. In Section 4 this instrument is applied to the pork marketing chain in the Netherlands. In Section 5 the main conclusions are summarized and directions for further research are proposed.

2. Models

Price coordination in marketing channels aims at relating product prices at various stages of the marketing channel in such a way that the channel is performing well. It implies that product price changes at a particular stage of the channel, *ceteris paribus*, influence prices in other stages of the marketing channel. The extent of price coordination in the channel, and for that matter the absence of bottlenecks, depends on the price strategy of the respective channel companies. Therefore, monitoring a marketing channel for price coordination might profit from a conceptual framework of companies' price strategy vis á vis changing purchase prices. We suggest the following hierarchy in price coordination as a framework for monitoring bottlenecks in pricing. As a matter of convenience, we assume in our presentation a three-level marketing channel, e.g. producer, wholesaler and retailer, referred to as companies 1, 2 and 3 respectively, but our results can be generalized to a *p*-level channel.

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' 'Ad hoc' price coordination', price changes are coordinated only in case of substantial price changes.

In this situation companies fix their price without considering 'modest' price changes by other companies in the channel:

$$p_i = p_{i,s} + u_i, \tag{1a}$$
$$u_i = N(0,\sigma_i^2), \tag{1b}$$

where p_i is the selling price of company I ($I = 1,2,3$), $p_{i,s}$ is the structural price of company I and μ is a random term.

Companies have a price, $p_{i,s}$, in mind which they consider to be appropriate in view of the structural demand. Actual prices deviate from that price only by a random term. Company I does not change its selling price p_i vis á vis changes in the purchase price p_{i-1}. This case of absent price coordination in the channel seems relevant only in stationary markets or when the price p_{i-1} is a minor part of total costs per unit of company I, for example, in case of substantial processing of agricultural products. However, in dynamic markets purchase prices might change substantially and companies might use the additional criterion:

$$p_i - p_{i-1} > m_i, \tag{1c}$$

where m_i is the necessary contribution of p_i to other variable costs and overhead per unit of product than p_{i-1}. In case of substantial price changes this condition will often not be fulfilled and company I may now change its selling price in response to changes in the purchase price.

'Routinized price coordination', systematic price coordination by companies in the channel on the basis of a routine procedure.

Two situations can be distinguished:

a) Companies apply the same 'markup' as a routine procedure;
b) 'Follow the leader' as a price coordination procedure.

Ad a
Company I in the channel is using a specific markup as a routine procedure:

$$p_i = f(p_{i-1}, x_i), \tag{2}$$

where x_i are other price-influencing factors. This routine procedure, for example $p_i = \alpha_0$ +_α_1 p_{i-1} or p_i =_α_p_{i-1}, may have an economic basis, but cannot always considered to be a rational, optimizing procedure. In markets with frequent, e.g. daily, price changes, transaction costs of economically effective pricing per transaction might be too high. For that reason, companies use a routine procedure, which has proven to be economically viable. Such a procedure may be practised, for instance, by wholesalers and retailers in marketing channels of fresh produce.

Ad b
Companies adapt prices to changes in prices of the channel leader:

$$p_i = f(p_{cl}, x_i), \tag{3}$$

where p_{cl} is the price of the channel leader. For instance, in consumer-oriented marketing channels big retailers or food industries may initiate a price change if consumer demand is decreasing or increasing. Other companies in the channel will follow.

'Rational price coordination', coordination of channel prices aiming at profit maximization.

Also here two models can be distinguished:

a) partially rational price coordination;
b) fully rational price coordination.

Ad a
Individual companies in the channel, but not the channel as a whole, adapt prices to changes in purchase prices in order to maximize profit:

$$\text{Max } \Pi_i = (p_i - c_i - p_{i-1})q, \tag{4a}$$

subject to

$$\ln p_3 = (1/\delta_p)\ln q + s, \qquad (\delta_p < -1) \tag{4b}$$

where Π_i is the profit of company I, q is the product flow through the channel and c_i are the processing costs per unit faced by company I. The inverse demand equation (4b) is assumed to be log-linear so the price elasticity of demand, δ_p, is constant. s captures exogenous demand shifts. Π_3 will be maximized if:

$$\partial\Pi_3/\partial q = p_3 + q(\partial p_3/\partial q) - c_3 - p_2 = 0, \tag{4c}$$

leading to the following price equilibrium:

$$p_3 = (p_2 + c_3)\delta_p/(1 + \delta_p). \tag{4d}$$

Subject to (4d) the first-order condition with respect to maximization of Π_2 gives

$$p_2 = p_1\delta_p/(1+\delta_p) + (\delta_p c_2 - c_3)/(1+\delta_p), \tag{4e}$$

and finally, reminding that $\Pi_1 = (p_1 - c_1)q$, maximization of Π_1 determines p_3:

$$p_3 = \sum_{i=1}^{3} c_i [\delta_p / (1+\delta_p)]^3 . \tag{4f}$$

From (4f) and (4b) q can be derived.

Ad b
The companies determine jointly the price of the final channel product such that profits are maximized. This implies:

$$\text{Max}, \Pi_c = (p_c - \sum_{i=1}^{3} c_i) q \tag{5a}$$

subject to

$$\ln p_c = (1/\delta_p)\ln q + s, \quad (\delta_p < -1) \tag{5b}$$

where Π_c is the profit of the whole channel and p_c is the price of the final channel product. The first-order condition of the profit maximization problem is:

$$\partial\Pi_c / \partial q = p_c + q(\partial p_c / \partial q) - \sum_{i=1}^{3} c_i = 0 , \tag{5c}$$

giving

$$p_c = \sum_{i=1}^{3} c_i \delta_p / (1+\delta_p) . \tag{5d}$$

Because $\delta_p < -1$, comparing (4f) with (5d) shows that $p_c < p_3$ and hence, q will be greater at p_c than at p_3 and so Π_c will be greater than $\Pi_1 + \Pi_2 + \Pi_3$ of the partially rational price coordination model.

Equilibrium price relationships can be derived e.g. by assuming that companies 1 and 2 charge a two-part tariff (Tirole, 1988: 176):

$$p_i q = A_i + \sum_{j=1}^{i} c_j q . \tag{5e}$$

From (5a) it follows that

$$p_c = \Pi_c / q + \sum_{j=1}^{3} c_j , \tag{5f}$$

so company 2 charges company 3

$$p_2 = \alpha_2 \Pi_c / q + c_1 + c_2 = \alpha_2 (p_c - \sum_{j=1}^{3} c_j) + c_1 + c_2 , \tag{5g}$$

with $0 \le \alpha_2 \le 1$, and, in turn, company 1 charges company 2

$$p_1 = \alpha_1 \alpha_2 \Pi_c / q + c_1 = \alpha_1 (p_2 - c_1 - c_2) + c_1 , \tag{5h}$$

with $0 \le \alpha_1 \le 1$. From (5g) and (5h) it can be seen that company 2 takes α_2 part of Π_c away from company 3, while company 1 takes α_1 part of $\alpha_2 \Pi_c$ away from company 2. The companies have to agree upon feasible values of α_1 and α_2.

The proposed hierarchy from ''*ad hoc' price coordination*', '*routinized price coordination*' to '*rational price coordination*' suggests that the more rational companies are, the more price coordination is grounded on economic factors such as costs and price elasticity of demand. Nevertheless, except for the ad hoc price coordination situation, all price coordination models in our hierarchy result in bivariate equilibrium (i.e., static or, similarly, long-run) price relationships. So what we have learnt from this theoretical section that only deals with static models, is that if empirical evidence is found of bivariate vertical equilibrium price relationships between all prices in the chain, then the ad hoc price coordination model does not apply in the long run. In the short run all stages may be involved in trying to re-establish the price equilibria after an equilibrium error occurred, but there can also be one stage whose price does not show error-correcting behaviour. Therefore, although prices are in equilibrium in the long run, we do not know whether or not all stages are involved in maintaining the long-run price relationships. The stage that is not involved, might be considered to cause a bottleneck in price coordination, because its pricing strategy does not take the pricing interests of the other stages into account, which may, for example, hamper a joint marketing operation by the successive companies in the agricultural marketing channel vis á vis the consumer.

As a consequence, in addition to studying the static price relationships, as e.g. in Larue (1991), we must also consider short-run price dynamics that show how these equilibrium price relationships are affected and reestablished after a price shock (innovation) occurs in one of the channel stages. In the next sections this investigation will be carried out by vector error-correction modelling and applied to the Dutch pork production-marketing chain. The analysis gives answer to the questions whether or not prices are coordinated in an ad hoc way and if not, which of the models, the routinized, the partially rational and the fully rational model, are consistent with the data and whether or not one of the stages does not make an effort to maintain price coordination within the marketing chain.

3. Method

Let $X_t = (p_{1t},...,p_{pt})'$ be a vector of p prices, where p_{it} ($I = 1,...,p$) is the output price of stage I in the marketing channel and $p \geq 2$ is the total number of stages in the marketing channel in which stage 1 is upstream and stage p is downstream.

If we assume that the time series of the x_i and c_i variables in the routinized and rational price coordination models, see Section 2, as well as the first differences of p_{it}, i.e., Δp_{it} ($= p_{it} - p_{i,t-1}$), show a constant-mean or trend-reverting pattern, while the graph of the price series in levels, i.e., p_{it}, is characterized by long periods of prices that are higher or lower than the average price level or overall linear trend regarding the whole period shown in the graph, then it is said that x_{it}, c_{it} and Δp_{it} are stationary, whereas p_{it} is non-stationary. Because x_{it} and c_{it} are already stationary in levels while the p_{it} series becomes stationary after taking first differences, it is said that x_{it}, c_{it} and Δp_{it} are integrated of order zero, denoted $I(0)$, and p_{it} is integrated of order one, denoted $I(1)$.

$I(1)$ variables can be transformed to stationarity not only by taking first differences, but also by cointegration, i.e., by taking a certain (unique) linear combination of the $I(1)$ variables. Such a linear combination represents a long-run equilibrium relationship and the outcome of the linear combination displays the equilibrium error. Since $I(1)$ variables dominate $I(0)$ variables and because there can never be a relationship between an $I(1)$ variable and an $I(0)$ variable, the routinized and rational price coordination models imply p - 1 bivariate long-run equilibrium price relationships as follows:

$$p_{it} = \beta_{0,i,i-1} + \beta_{1,i,i-1}p_{i-1,t} + e_{i,i-1,t}, \tag{6}$$

where $I = 2,...,p$, the β's are parameters with $\beta_{1,i,i-1} > 0$, and $e_{i,i-1,t}$ is $I(0)$ representing the short-run deviations from the equilibrium (i.e., the equilibrium error). A multivariate time-series model must be used to find evidence of (6) and to show how prices respond if one of them causes a disequilibrium. In this study we employ Johansens's maximum likelihood (ML) procedure (Johansen, 1988, 1991 and 1995b; Johansen and Juselius, 1990, 1994) for estimation of a vector error-correction model (VECM) of the prices. Clear introductions in cointegration and error-correction can be found in Charemza and Deadman (1992), Rao (1994), Enders (1995) and Harris (1995).

Starting point of the Johansen procedure is a vector autoregressive model of order k, denoted VAR(k), that can be rewritten as

$$\Delta X_t = \Pi X_{t-1} + \sum_{j=1}^{k-1}\Gamma_j \Delta X_{t-j} + \mu + \Phi D_t + \varepsilon_t \,', \tag{7}$$

where $\Delta X_t = X_t - X_{t-1}$, μ are the intercepts, D are centred seasonal dummies which sum to zero over a full year, $\epsilon_1,...,\epsilon_T$ are $IIN_p(0,\Lambda)$ and $X_{k+1},...,X_0$ are fixed. Suppose that X_t is $I(1)$, then the coefficient matrix Π contains information about the long-run price relationships. Consequently, if rank(Π) = r with $0 \leq r < p$, then there are r long-run (i.e., cointegration) relationships and Π can be expressed as the outer product of two (full column rank) ($p \times r$) matrices α and β:

$$\Pi = \alpha\beta', \tag{8}$$

such that $\beta' X_t$ is $I(0)$ in which case (7) is called a VECM. The columns of β are called the cointegrating vectors and can be identified by imposing restrictions as follows:

$$\beta = (H_1\phi_1,..., H_r\phi_r), \tag{9}$$

where H_j ($j = 1,...,r$) is a ($p \times s_j$) matrix reducing the p-dimensional vector β_j to the s_j-dimensional vector ϕ_j with $1 < s_j < p$. If μ can be restricted to be only included in the long-run price relationships, then the X_{t-1} term in (7) is replaced by the (p+1)-dimensional vector $(p_{1t},...,p_{pt}, 1)'$ letting β_j and H_j to obtain (p+1) rows. Then, in the case of the bivariate long-run price relationships in (6) (these relationships include two prices and an intercept, hence $s_j = 3$), before imposing the normalization restriction, the (j + 1)th element of the first column (allowing for the coefficient of the price that will be the dependent variable after normalization), the (p + 1)th element of the second column (allowing for the intercept) and the jth element of the third column (allowing for the coefficient of the price that will be the right-hand-side variable after normalization) of H_j are equal to one while all the other elements of H_j are zero.

To test for cointegration, trace statistics are used to determine r (Johansen and Juselius, 1990). Next, the system is checked for exact identification using the rank condition in Johansen (1995a) and the ML estimates of α and β are computed by the switching algorithm outlined in Johansen and Juselius (1994).

If prices are coordinated such that there are p - 1 cointegrating vectors (i.e., $r = p - 1$ cannot be rejected whereas $r < p - 1$ must be rejected), then we reject the ad hoc price coordination model in favour of the routinized and rational models. From the estimates of β further information can be obtained on which of the models, the routinized, the partially rational and the fully rational model, are consistent with the data. Moreover, in spite of $r = p - 1$, there can still be one stage that does not join the other stages in their effort to keep prices in equilibrium. Such a stage could be causing a bottleneck in price coordination. To outline the testable features of a bottleneck stage in price coordination, attention must be focused on the error-correction mechanism in (7). For illustrative purposes, let us consider the case in which $p = 2$, $k = 1$ and $r = 1$ so that after imposing (6) along the lines of (8) and (9), we can write (7) in full as

$$\Delta p_{1t} = \alpha_1(p_{2,t-1} - \beta_{01} - \beta_{11}p_{1,t-1}) + \mu_1 + \sum_{j=1}^{d-1}\Phi_{1j}D_{jt} + \epsilon_{1t}, \tag{10a}$$

$$\Delta p_{2t} = \alpha_2(p_{2,t-1} - \beta_{01} - \beta_{11}p_{1,t-1}) + \mu_2 + \sum_{j=1}^{d-1}\Phi_{2j}D_{jt} + \epsilon_{2t}, \tag{10b}$$

where, for example, $d = 12$ in case of monthly data. If $p_{2,t-1}$ is higher (smaller) than its long-run equilibrium level given by $\beta_{01} + \beta_{11}p_{1,t-1}$, then Δp_{2t} decreases (increases) given that $-2 < \alpha_2 < 0$, so that p_{2t} changes to eliminate the deviation from long-run equilibrium. Moreover, if $-2 < -\alpha_1\beta_{11} < 0$, then p_{1t} is changing as well to eliminate the disequilibrium between both prices. However, if $\alpha_1 \leq 0$ ($\alpha_2 \geq 0$), then the $\{p_{2t}\}$ ($\{p_{1t}\}$) sequence does all the correction to eliminate any deviation from long-run equilibrium. In that case, stage 1 (stage 2) is considered to cause a bottleneck in price coordination. There is, however, one exception. If $\alpha_1 = 0$ ($\alpha_2 = 0$), then stage 1 (stage 2) can be considered to be the channel price leader instead of causing a bottleneck, see Hall and Milne (1994) on the definition of long-run causality. In general, if $r = p - 1$ and the ith row of α is a zero row, then stage I will be the channel price leader. If the ith row of α is not a zero row, it depends on the elements of this row whether or not stage I is causing a bottleneck. This will be worked out in the next section where an empirical application is presented to illustrate the methodology in the general case, i.e., the case in which the marketing channel contains three or more stages.

4. Application

We consider the marketing channel of pork in the Netherlands, see, for example, Den Ouden et al. (1996). Four stages are distinguished ($p = 4$): the breeders (stage 1), who produce the piglets; the fatteners (stage 2), who produce the fattened pigs; the slaughterhouses (stage 3), which produce the pork; and lastly, the retailers (stage 4), who sell the pork to the consumers. Consequently, the dataset contains the piglet price, p_1 (Dfl/piglet), the price of fattened pigs, p_2 (Dfl/100kg slaughter weight), the price index of pork at the slaughterhouse level, p_3 (1985 = 100), and the retail price of pork, p_4 (Dfl/kg lean meat). All prices are deflated by the Dutch consumer price index (1985 = 1.00). Our sample consists of monthly data from January 1989 up to and including May 1994 (65 observations). The data and their sources are available from the authors upon request.

Table 1 VAR order determination

k	0	1	2	3	4	5
FPE	3802	34.64	33.11	42.74	64.13	115.44
AIC	6.53	1.80	1.69	1.85	2.11	2.48
HQ	6.53	2.02	2.14	2.52	3.00	3.59
SC	6.53	2.37	2.84	3.57	4.40	5.52
p-value LR(16)	0.00	0.07	0.65	0.92	0.99	0.21
r		2	3	1	0	0
p-value LR(1)		0.79	0.96	0.54	0.67	0.47

First, the order of the VAR, k, is determined as well as the number of cointegrating vectors, r, see Table 1. Four information criteria are computed: FPE, AIC, HQ and SC, see Lütkepohl (1991). The estimate for k is chosen such that the criterion is minimized. FPE and AIC select $k = 2$, while HQ and SC estimate $k = 1$. However, at $k = 1$ the likelihood ratio test testing 16 restrictions, denoted LR(16), rejects VAR(1) against VAR(2) at the 10% level. Moreover, a VAR(2) complies with $p - 1 = 3$ cointegrating vectors as selected by Johansen's trace statistic (see Table 2), where we use those 90% quantiles, denoted trace(90%), that comply with the result that the LR(1) test (see Table 1) does not reject the restriction according to which μ is only included in the cointegrating space (for the LR test concerning μ, see Johansen and Juselius, 1990; the critical values are obtained from Table 1* in Osterwald-Lenum, 1992: 467). Based on these results we tentatively conclude that $k = 2$ and $r = 3$.

Table 2 Cointegrating rank determination (k = 2)

r	0	1	2	3
trace	71.93	39.01	19.42	3.77
trace (90%)	49.65	32.00	17.85	7.52

The $r = p - 1 = 3$ result is in line with the routinized and rational price coordination models discussed in Section 2. After normalization, the estimated cointe-grating vectors lead to the following long-run equilibrium price relationships (t-values in parentheses are asymptotically $N(0,1)$ distributed):

$$p_{2t} = \underset{(4.64)}{55.98} + \underset{(10.21)}{2.13} p_{1t} + \hat{e}_{21t}\,, \tag{11a}$$

$$p_{3t} = \underset{(16.02)}{15.68} + \underset{(35.33)}{0.19} p_{2t} + \hat{e}_{32t}\,, \tag{11b}$$

$$p_{4t} = \underset{(12.95)}{3.85} + \underset{(20.20)}{0.05} p_{3t} + \hat{e}_{43t}\,. \tag{11c}$$

All cointegrating parameter estimates are highly significant and have the correct sign. Hence, as far as this limited evidence goes, we conclude that channel companies do not exhibit 'ad hoc' price coordination. In addition, the estimated parameters of the prices in (11a)-(11c) can be used to check which of the models, the routinized, the partially rational and the fully rational model, are supported by the data. For this purpose, we first have to correct the parameter estimates for the measurement units of the prices. To compare the price of piglets (Dfl/piglet) with the price of pigs (Dfl/100kg slaughter weight), one must know that one fattened pig yields about 85 kg slaughter weight. Consequently, the corrected estimate for the parameter of p_{1t} in (11a) is found as $\beta_{121} = (85/100) \times 2.13 = 1.81$. Furthermore, p_{4t} is the price of a kilogramme lean meat while p_{2t} is the price per 100 kg slaughter weight. The average lean-meat percentage is 55 percent. Thus, if we substitute (11b) in (11c), then we obtain the following for measurement units corrected estimate of the parameter attached to p_{2t} in the equilibrium relationship between p_{4t} and p_{2t}: $\beta_{142} = 55 \times 0.05 \times 0.19 = 0.52$.

In the fully rational price coordination model $\beta_{121} = 1/\alpha_1$, see (5h), and $\beta_{142} = 1/(\alpha_2 \alpha_3)$, as can be derived from generalising (5f)-(5h) to a four-stage channel. Since $0 \leq \alpha_i \leq 1$ ($I = 1,2,3$), it can be seen that the estimate of 1.81 for β_{121} fits into this model. However, the estimate of 0.52 for β_{142} is clearly not in favour of the fully rational price coordination model. Consequently, we conclude that the fully rational price coordination model does not apply.

In the partially rational price coordination model $\beta_{121} = \delta_p/(1 + \delta_p)$, see (4e), and $\beta_{142} = [\delta_p/(1 + \delta_p)]^2$, as can be derived from substituting (4e) in (4d) while generalising to a four-stage channel. Substituting the estimates of β_{121} and β_{142} we obtain $\delta_p = -2.23$ from $1.81 = \delta_p/(1 + \delta_p)$ and $\delta_p = 2.59$ from $0.52 = [\delta_p/(1 + \delta_p)]^2$. The second estimate of δ_p does not comply with the theory and hence, the partially rational price coordination model should also be rejected.

So far, we checked all price coordination models in our hierarchy apart from the routinized model. Because all models being checked were rejected, our hierarchy allows only the routinized price coordination model to apply. If we take the sample average of the undeflated prices and adjust the intercept terms in the long-run price relationships in (11a)-(11c) accordingly (the undeflated average price is equal to 1.8 times the deflated one, so the intercept term in the long-run relationship between p_{2t} and p_{1t} becomes $1.8 \times 55.98 = 101$ and the intercept term in the long-run relationship between p_{4t} and p_{2t} will be $1.8 \times (3.85 + 0.05 \times 15.68) = 8.34$), we obtain the following markup rules: $p_{2t} = 101 + 1.81 p_1$ and $p_{4t} = 8.34 + 0.52 p_{2t}$. The sample average of the undeflated prices p_1, p_2 and p_4 are 117.5 guilders per 100 kg slaughter weight, 315 guilders per 100 kg slaughter weight (or 5.73 guilders per kg lean meat) and 11.35 guilders per kg lean meat, respectively. Notice that these averages nicely comply with the markup rules and imply that in the long run a ten percent increase in p_1 leads to a 6.8 percent increase in p_2 which in turn leads to a 1.8 percent increase in p_4, and a ten percent increase in p_2 results in a 2.6 percent increase in p_4.

Moreover, the result that the coefficient of p_{2t} in the markup rule $p_{4t} = 8.34 + 0.52 p_{2t}$ is smaller than one, implies that fluctuations in the buying price p_{2t} are dampened in the retail price, so that the absolute margin ($p_{4t} - p_{2t}$) fluctuates opposite to the buying price p_{2t}. This phenomenon, which is well-known in the literature as a characteristic of 'levelling', was also found by Van Dijk (1978: 166, 167) whose investigation of the relationship between retail and wholesale prices of pork in The Netherlands, using quarterly data for the period 1961 - 1973, led to the conclusion that of a unit change in the wholesale price 72% is reflected in the retail price. Levelling policies in pricing by retailers may, for example, be evoked if consumer demand is more elastic at higher prices than at lower prices (a linear demand function has this property) so that the profit-maximizing retailers will vary absolute margins inversely with buying prices and price elasticity of demand, assuming the raw material is the main cost item for the retailer. See Van Dijk (1978) and the references cited therein.

Next, to investigate whether or not one of the stages causes a bottleneck or behaves as a channel leader in price coordination, the parameters in the VECM are estimated conditional on the long-run parameter estimates in (11a)-(11c). Notice that it does not make any difference whether we include the set of error-correction terms given by ($\hat{e}_{21,t-1}$, $\hat{e}_{32,t-1}$, $\hat{e}_{43,t-1}$), ($\hat{e}_{12,t-1}$, $\hat{e}_{13,t-1}$, $\hat{e}_{14,t-1}$), ($\hat{e}_{21,t-1}$, $\hat{e}_{23,t-1}$, $\hat{e}_{24,t-1}$), ($\hat{e}_{31,t-1}$, $\hat{e}_{32,t-1}$, $\hat{e}_{34,t-1}$) or ($\hat{e}_{41,t-1}$, $\hat{e}_{42,t-1}$, $\hat{e}_{43,t-1}$) in the VECM.

Nevertheless, if we want to determine whether or not p_{It} ($I = 1,...,4$) shows error-correcting behaviour, it is most convenient to include the set in which the first index of each equilibrium error is given by I.

Consequently, to test whether or not stage 1 causes a bottleneck or behaves as a price leader, βX_{t-1} is replaced by $(\hat{e}_{12,t-1}, \hat{e}_{13,t-1}, \hat{e}_{14,t-1})'$ in (7). Next, the parameters in (7) are estimated by OLS and the variable with statistically the most insignificant coefficient is deleted from the equation that included this coefficient (intercepts, however, are never deleted). The model is then reestimated using the method of seemingly unrelated regressions (SUR). Potentially, a parameter is again set to zero and this process is repeated until all of the regressors have significant coefficients (i.e., probability < 0.05). In this way, the following equation was found for Δp_{1t} (standard errors in parentheses, probabilities between brackets):

$$\Delta p_{1t} = \underset{(0.56)}{-0.14} + \underset{(1.88)}{5.33D_{1t}} + \underset{(2.53)}{6.81\Delta p_{4,t-1}} + \underset{(0.18)}{0.50\hat{e}_{12,t-1}} - \underset{(0.15)}{0.70\hat{e}_{13,t-1}} + \underset{(0.05)}{0.23\hat{e}_{14,t-1}} + \hat{\varepsilon}_{1t}, \qquad (12)$$

$T = 63$ (89.03 - 94.05); $R^2 = 0.47$; $\hat{\sigma} = 4.43$; $AR1\text{-}1$ $F(1, 55) = 0.21$ [0.65]; $AR1\text{-}4$ $F(4, 49) = 0.62$ [0.65]; $ARCH1\text{-}1$ $F(1, 60) = 2.60$ [0.11]; $NORM$ $\chi^2(2) = 0.98$ [0.32]; $HETEROSC$ $F(4, 53) = 0.45$ [0.77]; $RESET1\text{-}3$ $F(3, 54) = 0.07$ [0.97]; $BREAK92$ $F(6, 51) = 1.80$ [0.12]; $FORCST94$ $F(5, 52) = 0.82$ [0.54],

where T denotes the number of observations, σ is the standard deviation of the regression, $AR1\text{-}I$ tests for the absence of ith order autocorrelation, $ARCH1\text{-}1$ tests for the absence of first order autoregressive conditional heteroscedasticity, $NORM$ is the Jarque-Bera statistic that tests whether ϵ_t is normally distributed, $HETEROSC$ tests for the absence of heteroscedasticity quadratic in regressors (no cross terms), $RESET1\text{-}I$ tests for the absence of ith order RESET, $BREAK92$ is the Chow breakpoint statistic that tests for the absence of parameters whose values regarding the sample 89.03 - 91.12 differ from their values regarding the sample 92.01 - 94.05, $FORCST94$ is the Chow forecast statistic that tests for the absence of parameters whose values regarding the sample 89.03 - 93.12 do not apply for the sample 94.01 - 94.05. We refer to Kuiper (1994) or Hendry (1995) for more details. None of the diagnostic test statistics reveal model misspecification in (12).

To see what the parameter estimates in (12) tell us about the question whether or not p_{1t} is error-correcting, we have to consider the parameter estimates of the error-correction terms $\hat{e}_{12,t-1}$ ($= p_{1,t-1} - 0.47p_{2,t-1} + 26.27$), $\hat{e}_{13,t-1}$ ($= p_{1,t-1} - 2.43p_{3,t-1} + 64.37$) and $\hat{e}_{14,t-1}$ ($= p_{1,t-1} - 49.30p_{4,t-1} + 253.97$). These estimates are 0.50, -0.70 and 0.23. Note that the sum of these estimates is almost equal to zero. If we test this restriction we obtain a $\chi^2(1)$ statistic of 0.08 implying a probability of 0.77. Hence, we cannot reject the hypothesis that the parameters of the error-correction terms in (12) sum to zero, leading to the conclusion that $p_{1,t-1}$ is not included in the error-correction mechanism of the equation for Δp_{1t}. This implies that if p_{1t} causes an equilibrium error, then the prices of the other stages must be called in to do the correction. Nevertheless, stage 1 is not the channel price leader, because if it had been the channel price leader, then the parameters of the error-correction terms in (12) would have been zero. Consequently, stage 1 causes a bottleneck in price coordination.

Because $r = p - 1$, there cannot be a bottleneck nor a price leader among the other stages in the channel. This is confirmed by the equations for Δp_{2t}, Δp_{3t}, and Δp_{4t} that were found when applying model selection to (7) each time βX_{t-1} was replaced by one of the vectors $(\hat{e}_{21,t-1}, \hat{e}_{23,t-1}, \hat{e}_{24,t-1})'$, $(\hat{e}_{31,t-1}, \hat{e}_{32,t-1}, \hat{e}_{34,t-1})'$ and $(\hat{e}_{41,t-1}, \hat{e}_{42,t-1}, \hat{e}_{43,t-1})'$.

$$\Delta p_{2t} = \underset{(1.15)}{-0.21} - \underset{(2.20)}{4.76D_{3t}} + \underset{(2.21)}{5.20D_{6t}} + \underset{(0.50)}{2.16\Delta p_{3,t-1}} + \underset{(2.76)}{6.63\Delta p_{4,t-1}} - \underset{(0.05)}{0.27\hat{e}_{21,t-1}} - \underset{(0.09)}{0.57\hat{e}_{23,t-1}} + \hat{\varepsilon}_{2t}, \qquad (13)$$

$T = 63$ (89.03 - 94.05); $R^2 = 0.49$; $\hat{\sigma} = 9.57$; $AR1\text{-}1$ $F(1, 54) = 0.01$ [0.91]; $AR1\text{-}4$ $F(4, 48) = 0.39$ [0.82]; $ARCH1\text{-}1$ $F(1, 60) = 0.02$ [0.89]; $NORM$ $\chi^2(2) = 2.36$ [0.12]; $HETEROSC$ $F(4, 52) = 0.17$ [0.95]; $RESET1\text{-}3$ $F(3, 53) = 2.83$ [0.05]; $BREAK92$ $F(7, 49) = 1.21$ [0.31]; $FORCST94$ $F(5, 51) = 1.21$ [0.32],

$$\Delta p_{3t} = \underset{(0.24)}{-0.06} + \underset{(0.11)}{0.28\Delta p_{3,t-1}} - \underset{(0.05)}{0.13\hat{e}_{31,t-1}} + \hat{\varepsilon}_{3t}, \qquad (14)$$

$T = 63$ (89.03 - 94.05); $R^2 = 0.20$; $\hat{\sigma} = 1.86$; $AR1\text{-}1$ $F(1, 58) = 0.37$ [0.55]; $AR1\text{-}4$ $F(4, 52) = 0.58$ [0.68]; $ARCH1\text{-}1$ $F(1, 60) = 0.00$ [0.96]; $NORM$ $\chi^2(2) = 3.23$ [0.07]; $HETEROSC$ $F(2, 58) = 0.04$ [0.96]; $RESET1\text{-}3$ $F(3, 57) = 1.22$ [0.31]; $BREAK92$ $F(3, 57) = 0.98$ [0.41]; $FORCST94$ $F(5, 55) = 0.62$ [0.69],

$$\Delta p_{4t} = \underset{(0.02)}{-0.00} - \underset{(0.08)}{0.21 D_{1t}} + \underset{(0.07)}{0.23 D_{4t}} + \underset{(0.07)}{0.17 D_{6t}} +$$

$$\underset{(0.07)}{0.15 D_{7t}} + \underset{(0.07)}{0.16 D_{8t}} - \underset{(0.07)}{0.23 D_{0t}}$$

$$- \underset{(0.07)}{0.18 D_{11t}} - \underset{(0.08)}{0.58 \hat{e}_{42,t-1}} + \hat{\varepsilon}_{4t}, \qquad (15)$$

$T = 63$ (89.03 - 94.05); $R^2 = 0.65$; $\hat{\sigma} = 0.15$; *AR*1-1 $F(1, 52) = 2.83$ [0.10]; *AR*1-4 $F(4, 46) = 0.33$ [0.85]; *ARCH*1-1 $F(1, 60) = 0.17$ [0.68]; *NORM* $\chi^2(2) = 5.22$ [0.02]; *HETEROSC* $F(1, 53) = 0.08$ [0.78]; *RESET*1-3 $F(3, 51) = 0.57$ [0.64]; *BREAK*92 $F(9, 45) = 1.03$ [0.43]; *FORCST*94 $F(5, 49) = 1.04$ [0.40].

None of the diagnostic test statistics monitor serious misspecification (i.e., when several diagnostic test statistics have a probability smaller than 0.05 or when a single diagnostic test statistic has a probability smaller than 0.01). In each equation, (13), (14) and (15), the sum of the adjustment parameters lies between -2 and 0. Therefore, each of the prices, p_{2t}, p_{3t} and p_{4t}, is able to correct itself to eliminate the equilibrium error it caused.

5. Conclusions

In this paper we proposed a method for monitoring bottlenecks in price coordination within the production-marketing chain. Bottlenecks were defined as impediments at a particular stage of the marketing channel to adapt to price changes through the whole marketing channel of the respective product. We applied our method to analysing price coordination in the Dutch pork production-marketing chain. Starting with the upstream one, the following four stages were considered: the breeders (stage 1), who produce the piglets; the fatteners (stage 2), who produce the fattened pigs; the slaughterhouses (stage 3), which produce the pork; and lastly, the retailers (stage 4), who sell the pork to the consumers. The main conclusions are:

- The proposed framework and research methodology seem to be a useful instrument for monitoring a bottleneck stage with respect to price coordination in agricultural marketing channels. The methodology seems to be in particular useful for products that are processed to a minor extent in the channel, such as fresh products like pork.
- In the pork chain there are no structural bottlenecks in price coordination, i.e., in the long run the output price in each stage forms an equilibrium relationship with each of the output prices of the other stages. According to the equilibrium relationships we found that companies do not apply rational markup rules, which might leave room for improvement of coordination of channel prices aiming at profit maximization.
- None of the stages appear to be the price leader in the sense of driving the prices in the other stages in the long run.
- In the short run, breeders are found to cause a bottleneck in price coordination. If the price of piglets causes a deviation from the long-run equilibrium relationships with the prices of the downstream stages in the channel, then the breeders are not able to adapt the price of piglets to eliminate the equilibrium error without forcing the downstream stages, including the retailers, to change their prices. However, if we take into account that a joint marketing operation through the marketing channel vis á vis the consumer is often needed in order to achieve competitive advantage over rivals, it will be much better if wholesalers or retailers are allowed to change prices to meet the needs and wants of the consumer without being bounded to adjust their own price to the prices in the upstream stages of the marketing channel. Consequently, by concluding that breeders cause a bottleneck in price coordination through the chain, they can also be considered to hamper chain marketing.

Our analysis of bottlenecks can be extended along the framework proposed in Section 2 by analysing the long-run equilibrium price relationships in more detail, by introducing more variables, such as competitive prices, and by allowing for more than one firm per stage of the marketing channel (see, for example, Choi, 1996, and Wohlgenant, 1989, and the references cited therein). All these extensions, however, ask for a further elaboration of demand and cost functions.

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