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Short-run dynamics of feed ingredient prices facing the EC: a causal analysis

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ABSTRACT

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This paper attempts to (1) shed some light on the EC – US controversy concerning the effect of the EC oilseeds market regime on EC imports of US soybean products, essentially soy meal, and (2) provide information on another EC – US controversy: Does corn-gluten feed behave as a substitute for (EC view) or a complement to (US view) feed grains, and do EC corn-gluten feed imports displace EC grain production or not?

By using a constrained vectorial autoregressive model of Rotterdam prices for soy meal, sunflower meal, rape meal, corn-gluten feed and cassava, we show that (1) the decrease in EC imports of US soymeal are mot mainly caused by the EC milling subsidies, and (2) corn-gluten feed is both a substitute for soymeal due to its protein content and a substitute for cassava (and grains) due to its energy content: US and EC views are only partial views.

1. Introduction

The EC oilseed-protein market organisation allows free imports of oilseeds and oilmeals and maintains support to rapeseed and sunflower-seed domestic producers through the setting of annual target and intervention prices. Those prices being, most of the time, higher than corresponding world prices, milling subsidies equal to the gap between domestic and Rotterdam border prices are distributed by FEOGA, preferentially for Community products.

During the recent past, the U.S.A. has often criticized the EC oilseeds market regime. The most important dispute occurred in December 1987, with the complaint made in GATT against EC by the American Soybean

Association (ASA), which accused the Community of deliberately restricting the import and utilization of US soybeans and soybean meal. According to the ASA, this was in contravention with the Dillon Round Agreements, and the EC oilseed support policy should therefore be removed. The Community, for its part, claimed that the reduction in US exports was mainly due to (1) competition from South American producers in the soybean meal sector, (2) the increase in other meals imported from Third-World countries (copra from The Philippines and Indonesia, sunflower and flax from Argentina, rape seed from China and India, palm from Malaysia); and (3) the stagnation of the EC soybean-milling activity due to falling milling margins. The Community also claims that the EC still remains the world's greatest importer for oilseed products and that the rapid expansion of rapeseed and sunflower seed domestic production is now fully controlled via the Maximal Guaranteed Quantities mechanism.

The EC argues that the Community oilseeds system is approximately neutral since the quantities of meal demanded by the EC has increased faster than the EC domestic oilseed production during the last 7 years. Those policies had only a minor effect on domestic markets and no effect at all on world markets due to the absence of export subsidies. A related issue is that the EC domestic prices for the various oilseed products quickly reflect world prices.

The aim of this study is to shed more light on this controversy by focusing on causal relationships between the prices of the major animal feed ingredients on the Rotterdam market. More precisely, our objective is to analyse the direction and the strength of relationships between prices of imported feed ingredients which are not immediately covered by CAP regulations (soybean meal, corn-gluten feed and cassava) and feed ingredients produced within EC which are directly under the influence of CAP (rapeseed and sunflower meals). These results indicate which view (EC or US) is consistent with price series data. The analysis of the process by which equilibrium prices are reached will highlight substitution relationships among feed products. As a by-product, our results also provide some information on another EC – US controversy: Does corn-gluten feed (CGF) behave as a substitute for (EC view) or a complement to (US view) feed grains and do EC CGF imports displace EC grain production? Causality will be both analysed in a limited information bivariate framework and in a full information multivariate framework according to the lines proposed by Caines, Keng and Sethi (1981).

The remainder of the paper is organized as follows: the general background is presented in Section 2; the theoretical background and the empirical methodology are respectively presented in Sections 3 and 4; Section 5 reports and evaluates our empirical results; and Section 6 offers some concluding comments.

2. Background

The animal feed ingredients covered for this study are essentially purchased on the Rotterdam market by the EC compound-feed manufacturers. They altogether account for nearly 44.8% of total compound feed produced, while cereals account for 32.8%. The firms of the animal feed sector use cost-minimizing models in order to determine how much of the various feed ingredients they need for producing each kind of ration. These models take into account nutrient contents of the various ingredients, and their market prices. Ration formulae are more and more quickly adapted to price variations, at least several times a month.

Rotterdam (CIF or FOB ex Mill) prices (or sometimes Hamburg prices) are used as reference prices for all EC transactions, even when exchanged quantities do not physically transit through Rotterdam. Prices for these products on every EC market can thus be correctly calculated from corresponding Rotterdam prices and transportation costs.

The EC compound feed sector is directly related to four other sectors:

- cake importers (essentially soybean cake importers) which, apart from the cereal sector, constitutes the most important sector with imports close to 15 million t (of which 8.1 million t of soybean some mainly from Brazil).
- the EC crushing sector, which uses only imported seed (11 million t in cake equivalent) and especially soybean (10.0 million t in cake equivalent).
- gluten feed and cassava importers; with imports of about 4.8 million t for gluten feed (mainly from the U.S.) and 6.7 million t for cassava (mainly from Thailand).
- the EC crushing industry, using domestic EC production, is the sector which receives the crushing subsidy, representing the difference between the world price and the EC target price for oilseeds. Although the amount of EC domestic seed crushed (5.6 million t in cake equivalent) by this sector is much smaller than the amount of imported seed crushed by the first sector, this fourth sector plays a dominant role in the markets for sunflower and rapeseed cakes.

3. Theoretical Background

In this section, price relationships among the various animal feed ingredients are derived from the production program of the EC compound feed sector.

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t, metric tonne = 1000 kg.

Let us assume that the EC compound feed sector has a short-run cost-minimization behavior: it minimizes the variable cost of producing the vector of outputs Q_c conditional on the vector of quasi-fixed inputs Z and given prices p_X for variable inputs X. There exists a restricted cost function (RC), dual to the underlying transformation function:

$$\mathrm{RC} = \min_{X}[p_X', X; F(\bar{Q}_c, X, \bar{Z}) = 0] \tag{1}$$

$$= \mathrm{RC}(\bar{Q}_c, p_X, \bar{Z}) \tag{1'}$$

Assuming RC satisfies the usual regularity conditions[1], Shephard's lemma can be used to derive the conditional demand function for a variable input:

$$D_{x_i} = \partial\, \mathrm{RC}(\cdot)/\partial p_{x_i} = D_{x_i}(P_X; \bar{\theta}) \tag{2}$$

for i = CGF, soybean meal, rapeseed meal, sunflower meal and cassava, and for $\bar{\theta} = (\bar{Q}_c, \bar{Z})$

It may be assumed that feed ingredient quantities supplied on the Rotterdam market are nearly exogenous in the short run:

$$S_{x_i} = \overline{S_{x_i}} \quad \text{for every product } i \tag{3}$$

By assuming that these markets are in equilibrium we thus have:

$$D_{x_i}(P_X; \bar{\theta}) = \overline{S_{x_i}} \quad \text{for every } i \tag{4}$$

Since $\bar{\theta}$ is assumed fixed, linearization of this market-clearing condition around the approximation point gives:

$$\mathrm{d}p_{x_i} = \sum_{j \neq i} \alpha_{ij}\, \mathrm{d}p_{x_j} \quad \text{for every } i \tag{5}$$

with

$$\alpha_{ij} = [-(p_{x_i}\epsilon_{ij}^{D}) \,/\, (p_{x_j}\epsilon_{ij}^{D})]$$

where ϵ_{ij}^{D} is the demand elasticity for produce i with respect to the price for product j. Equation (5) may be rewritten in terms of price growth rates ($\dot{p}_{x_i} = \mathrm{d}p_{x_i}/p_{x_i}$) as:

$$\dot{p}_{x_i} = \sum_{j \neq i} \beta_{ij}\dot{p}_{x_j} \quad \text{for every } i \tag{5'}$$

with

$$\beta_{ij} = [-(\epsilon_{ij}^{D}/\epsilon_{ii}^{D})]$$

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[1] RC is non-decreasing in variable input prices, non-decreasing in output, non-increasing in quasi-fixed factors, positively linear homogeneous, concave, continous in variable input prices and twice differentiable with respect to variable input prices.

Assuming that own price-demand elasticities are negative ($\epsilon_{ii}^{\mathrm{D}} < 0$) for every product, both α_{ij} and β_{ij} coefficients may be positive or negative according to whether products are substitutes ($\epsilon_{ij}^{D} > 0$) or complements ($\epsilon_{ij}^{\mathrm{D}} > 0$).

In this respect, if we assume that Rotterdam prices for feed ingredients are primarily influenced by variations in quantities demanded by the compound feed sector in the short run, it is possible to clarify substitution – complementarity relationships among these products by estimating a reduced-form system such as (5) or (5′). This is precisely the case with vectorial autoregressive (VAR) models.

In this paper, we estimate such a system with a VAR methodology. This amounts to assuming that due to temporary market disequilibrium, relationships such as (5) are not instantaneously fully realized and that it takes time for a variation in the price of product i to be transmitted to price of product j. Disequilibrium may occur for several reasons: European feed compounders do not make instantaneous adjustments in response to a changing market situation; their plant machinery and mathematical programming techniques prevent them from substituting immediately from one commodity to another as relative prices vary, and available stocks, international transportation flows and shipping capacity change. If disequilibrium occurs, price relationships are recursive rather than simultaneous and the static price equations (5) have to be made dynamic. This leads to a dynamic reformulation of equations (5) in the following form:

$$\mathrm{d}p_{x_i} = \sum_{j \neq i} \alpha_{ij}(L)\, \mathrm{d}p_{x_j} + u_t \quad \text{for every } i \tag{6}$$

where $\alpha_{ij}(L)$ are lag polynomials. However, since the autoregressive coefficients of a VAR are not directly interpretable, substitution-complementarity relationships will be analysed on the basis of the dynamic multipliers derived from the VAR model.

4. Empirical methodology and data

During the recent past, many agricultural problems (lead-lag relationships between wholesale and retail prices and agricultural products; dynamic relationships between the price of a given commodity on different markets, etc.) have been treated by using bivariate causality analysis. However, the main drawback with such a method is that causality is only examined within a restricted information space. Often, considering a bigger information set reveals a different causal ordering than the one obtained with a bivariate procedure[2].

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[2] See for instance the case presented by Granger (1980, p. 30).

In this paper, multivariate causality analysis is done using a VAR model which includes the overall set of available time-series data:

$$D(L)\, Z_t = U_t \qquad (7)$$

where $D(L) = (I + D_1 L + D_2 L^2 + \ldots)$ is a matrix, the elements of which are p-order lag polynomials ($L^k Y_t = Y_{t-k}$)

The Caines – Keng and Sethi[3] modelling methodology allows the indentification of the coefficients of the $D(L)$ matrix without imposing the equality of lags on each variable and without appealing to a priori economic knowledge: all the information used in this method is derived from the data at hand.

This methodology is a sequential procedure based on Granger's concept of causality and Akaike's Final Prediction Error[4] criterion which allows each variable both to enter the model with a specific autoregressive order and to be explained by a sub-space of the whole set of available variables.

The Caines – Keng and Sethi procedure involves five steps:

(1) For each pair of stationary processes (X, Y) we first construct an optimal bivariate autoregressive model on the basis of the Akaike's FPE criterion.

(2) From such bivariate models, we then determine for each process X a set of n causal – in the Granger sense – variables ($Y^1, \ldots; Y^n$). The FPE obtained for each causal variable Y^i in previously estimated bivariate models (X, Y^i), $i = 1, \ldots, n$, are now used to rank these causal variables (with respect to X) in the order of increasing FPE.

(3) For each process X, the optimal univariate autoregressive models is first constructed using FPE criterion. The X's multiple causal variables are then included one at a time according to their causal ranks (determined in the previous step). At each step, FPE criterion is used to determine the optimal orders of the model. This third step leads to the optimal ordered univariate multivariable autoregressive model of X against its causal variables.

(4) All the optimal univariate autoregressive models are now estimated as a system with the FIML method.

(5) Several diagnostic checks are finally performed treating the tentatively identified system as the maintained hypothesis.

The final model is then used to determine the endogeneity, exogeneity or independance relations between the variables and to calculate the dynamic multipliers corresponding to each causal relationship.

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[3] Caines, Keng and Sethi (1981).

[4] Akaike (1970).

When causality links are not rejected by the data, calculation of associated dynamic multipliers quantifies such relationships among time series and allows investigation of the dynamic properties of the model.

Dynamic multipliers summarize the overall set of interactions that may exist among the endogeneous (caused) variable X and the exogenous (causal) variable Y^i. However, since in this analysis all predetermined variables are lagged endogenous variables, dynamic multipliers are calculated assuming a one-time stochastic shock occurring through the error term. They are thus calculated from the vectorial moving average form of the VAR:

$$Z_t = D^{-1}(L)\, U_t \tag{8}$$

In this paper, only 'long run' (which might better be called 'total') multipliers (LM_{xy_i}) will be presented. They provide a measure of the total impact on the expected variable X of a change in variable Y^i when a new equilibrium is reached. More precisely, if $\mathrm{IM}_{xy_i}^{(m)}$ is impact muliplier which shows the impact of a one-time change in variable Y^i in time t on the expected change in variable X in time $(t + m)$, then:

$$\mathrm{LM}_{xy_i} = \lim_{m \Rightarrow \infty} \frac{\partial E\,[X(t+m)]}{\partial Y_t^i} = \sum_{m=1}^{\infty} \frac{\partial E\,[\Delta X(t+m)]}{\partial Y_t^i} = \sum_{m=1}^{\infty} \mathrm{IM}_{xy_i}^{(m)}$$

In an attempt to measure the speed of adjustment of variable X following a change in Y^i, we calculated the number of time-periods (weeks) it takes for the sum of impact multipliers to stabilize within 5% of the long-run multiplier.[5]

Data used in this study are weekly Rotterdam (CIF) prices for soybean meal (44% protein), cassava, CGF and Argentinian sunflower cake (37–38% protein). Concerning rapeseed meal, we use the FOB ex Mill Hamburg price. All prices are nominal $US per t. The data period is 1 January 1981 to 16 July 1987. A first-order differentiation of the data was necessary in order to remove any linear time-trends and to achieve stationarity.

5. Empirical results

In this paper we present causality results obtained with both the traditional bivariate approach and the Caines–Keng and Sethi procedure.

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[5] This measure of the speed of adjustment is also used by Grant et al. (1983) and Boyd and Brorsen (1986). It may reflect the degree of inefficiency of the markets considered in terms of the time it takes for information to pass from one market to the other. It also provides an indication of the more or less proximity between markets due to distance between markets or difference in product composition.

However, only results obtained with this last method will be commented on due to their capacity to embody the whole set of available information.

A detailed presentation of causality results is given in the tables. Table 1 reports statistics derived from bivariate analysis, while results of the Caines – Keng and Sethi procedure are presented in Table 2 (see Appendix).

Causal links obtained with bivariate analysis reveal a quasi-general interaction of price series. However, lots of these relationships disappear with the Caines – Keng and Sethi procedure, which leads to the following causal structure (at the 5% confidence level).

Arrows indicate one-way causal link. Under each arrow are given the associated values of the long-run multiplier (·) and the adjustment period [·].

Figure 1 shows that the prices for cassava and for soybean meal are exogenous while the price of CGF is determined by all other prices.

More precisely, Fig. 1 reveals a three-level market structure. At the extremes are the pure energy feeds (cassava) and the 'pure' protein feeds (soybean meal).

The three products figuring at the intermediate market are feed ingredients characterized by a medium protein content: 23 – 24% for CGF, 34% for rapeseed meal and 37 – 38% for sunflower meal. According to their net energy contribution to pork and ruminant feed, cassava and soybean meal are rather energy-rich products. They are at least richer than rapeseed and sunflower meals, which contain a high degree of cellulose. CGF, which is specially used as ruminant feed, also has an energy content near that of barley or wheat, and is thus a dual-purpose ingredient in animal feed.

The causal structure presented in Fig. 1 is fully consistent with an examination of the nutrient compositions of each product. The import price for soybean cake directly determines, with relatively high associated multipliers, the price for CGF and for other cakes. Note that this result contradicts Boyd and Brorsen (1986), who found an instantaneous feedback relationship between the Rotterdam price for soybean meal and CGF with an associated correlation coefficient close to 0.45, which indicates that these

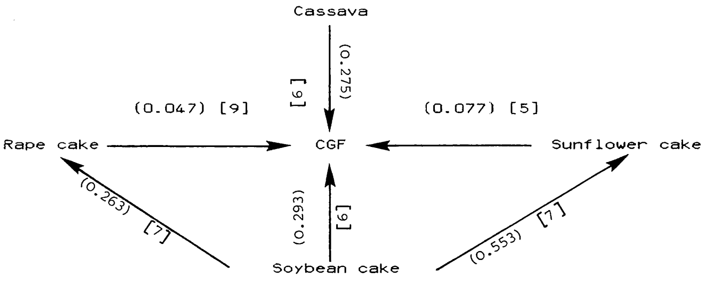

Fig. 1. Causal relationships between the prices of animal feed ingredients.

two products behave as substitutes. Although we reach the same conclusion concerning substitutability, since we estimated a positive multiplier, we obtain (with both methods) a significant one-way causality running from soybean meal to CGF and a multiplier near 0.3 (the bivariate approach leads to a multiplier of 0.39, which is closer to the correlation coefficient of Boyd and Brorsen).

Figure 1 clearly shows that soymeal behaves as a leader in the market for protein-rich products. Especially, causal relationships running from soybean cake prices to prices for rapeseed cake and sunflower cake are 'feedback-free'. This seems to be fully consistent with the EC argument that the EC crushing subsidies have no effect at all on the import price for soybean cakes: crusher subsidies are calculated in such a way that the decrease in soybean cake import prices cannot be explained by a deliberate cut in prices set by EC crushers. Prices for EC domestic cakes thus only passively follow world prices for soybean cakes.

Another point highlighted by Fig. 1 is that whereas CGF, rapeseed and sunflower meals are rather similar products according to their protein content and the sectors where they are used, there is no causal relationship running from CGF prices to the prices for rapeseed meals and sunflower meals. Such one-way causal links might reveal some degree of preference for Community commodities. A reduction in the price for CGF then leads to an increase in the demand for this product, without ultimately reducing the prices for the two other cakes. This may be due to the fact that rapeseed cake and sunflower cake remain highly competitive.

The estimated long-run multipliers are all lower than what might be expected on the grounds of protein contents. This seems to confirm the idea that, due to the fact that the ratio of the price of energy to the price of protein is higher within EC than on the world markets, energy plays an important part in the determination of the prices of the various animal feed ingredients. The price of soybean meal itself is determined partly by its energy content and partly by its protein content. As a consequence, by modifying the marginal value of protein and energy, an increase in the price for soybean meal has a net impact on each product which is a function of both its energy and protein content. This may be an explanation for both the somewhat low values of our multipliers and for the fact that CGF appears more influenced by soybean meal than by rapeseed meal since whereas CGF contains less protein than rapeseed, its energy content is higher than rapeseed.

The one-way causal link running from the import price for cassava to the import price for CGF may be surprising at first sight, since the first of these products is used for pork while the second is used for cattle feed. However, these two products are essentially energy products. Their prices are thus strongly related to the marginal cost of energy which is, in the EC, greatly determined by cereal prices.

The multipliers attached to the relationships cassava/CGF and soybean-meal/CGF are both positive and of nearly the same magnitude. This seems to confirm the fact that CGF plays a double game within animal feed. It is both a substitute for soybean meal and a substitute for energy products.

As a result both the European view, according to which CGF is a CSP (cereal substitute product), and the US thesis which holds that CGF is a protein-rich product and a substitute for EC soybean meal, appear as only partial views. Reality seems to lie between these two polar views.

We must note that our VAR model does not incorporate the price of cereals. This is a serious limit to our study since cereals amount to nearly 30% of the typical animal feed ration. However, the elaboration of weekly price series data for cereals is not straightforward. Rotterdam cereal prices are a measure of the world prices for cereals. They are very different from grain prices paid by European feed compounders since they do not incorporate variable levies. Thus, in order to correctly take grain prices into account in our study, a relevant price series should be constructed reflecting the weekly price used by compounders in their optimal formulae.

As was seen above, the price for energy and protein constitute the two main transmission mechanisms among the prices of animal feed ingredients. However, cereal price plays a central role in the determination of the marginal value for energy. It may thus be the case that the relationship we find between cassava and CGF is artificial and is due to the absence of cereal price in our model. Taking into account such a price would then probably wipe off the cassava/CGF relationship and replace it by relationships running from cereal prices to the prices for cassava and CGF. In this case, multipliers derived from such relationships should be relatively high due to the high energy content of these three products.

Since it seems sensible to suppose that world prices for these products are not only determined via their energy protein content but also by monetary factors, we have to note that several causality tests between the prices for these product and the $/ECU exchange rate were also performed.

The expected relationship running from the ECU value of the US dollar to the price for soybean meal was always rejected by the methodology. The only causal link obtained lies from the $/ECU exchange rate to the price for CGF with an estimated multiplier close to 0.08 and a 9-week adjustment period. This result is not surprising at all. CGF is essentially produced by the U.S.A. and 95% of this production is imported by EC. As a result, any variation in the EC demand for US soybean meal induced by a modification of the $/ECU exchange rate must have a non-negligible effect on the Rotterdam price for CGF (according to our results a 1% decrease in the value of the $/ECU exchange rate seems to lead to an increase in the Rotterdam price for CGF by 0.081%). This result confirms previous results from Boyd and Brorsen that the Rotterdam price for gluten feed causes the Chicago price for this product and that the price for CGF is thus discovered on the demand side of the CGF world market[6].

6. Concluding remarks

The dynamic relationships we found between the Rotterdam price of oilcakes, CGF and cassava shed some light on the co-behavior of these products and of the corresponding market. If we admit that short-run price variations for those products are mainly due to shifts in the EC compound feed industry demand, then calculated long-run multipliers highlight the substitution/complementarity relationships between the retained products within animal feed. These results provide a complementary approach to the analysis of nutrient compositions. Whereas nutrient composition plays an essential part in the associations of the various animal feed ingredients, the fact that within the EC the price of energy has a greater influence on the cost of feed rations than the price of protein, together with the wide range of substitute commodities available to feed compounders, make it difficult to have a precise idea of degrees of substitutability/complementarity between the various feed ingredients.

Substitution relationships obtained between the various cakes are all consistent with nutrient compositions. Causal links show that soybean meal behaves as a market leader in the pricing process for both rapeseed and sunflower cakes: causal relationships running from soybean price to sunflower and rapeseed meals are ‘feedback free’. Thus, it seems that EC imports for US soybean cakes do not result from a ‘spurious’ reduction in the price for EC domestic cakes (produced with EC domestic seeds) induced by EC crushing subsidies.

However, it is not possible to conclude that the EC oilseed/protein market organisation is totally neutral by solely focusing on meal markets. Whereas soybeans (which are highly protein-rich) prices are essentially a function of their meal content, the price of oil plays an essential part in the prices for sunflower and rapeseed for which oil contents are higher than for soybeans. Thus, in order to get a pricese idea about the global neutrality of the EC oilseed/protein regime, it is also necessary to focus on two other points: (1) price relationships among oil markets, and (2) whether or not rapeseed and sunflower oils have a greater influence on world oil prices due to EC subsidies. Although there are reasons for thinking that such an assumption is

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[6] Boyd and Brorsen (1986, p. 20).

true in the case of rapeseed, we must keep in mind that public interventions are frequent in this sector, as can be seen with the US EEP program.

Concerning CGF, it was found that this product plays a dual role within the compound-feed process. It is both a substitute for soybean meal due to its protein content and a substitute for cassava due to its energy content. As a result, even if we believe in the US view which claims that CGF is mainly a high-protein feed substitute and that CGF imports do not displace EC grain nor contribute to EC grain surpluses, our results seem to show that CGF also behaves as an energy substitute. This conclusion is fully consistent with the EC point of view which contends that CGF is essentially a CSP.

Future research on this subject could include a re-examination of causality relationships with a wider data set including the EC domestic prices for the main cereal products.

During the last 15 years, the rise in EC imports for cassava, CGF and soybean meal together with the simultaneous growth in domestic cereal production exacerbated the internal CAP contradictions and the need for a 'more balanced protective structure'[7]. Variations in Rotterdam prices for the main imported (or exported) commodities are influenced by forces coming from both EC and world markets. An analysis of dynamic relationships between these prices is thus a good way to better understand market interactions and improve the effects of policy intervention.

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[7] Mahé (1984).

Appendix

TABLE 1

Causality results, long-run multipliers and adjustment period obtained with bivariate analysis of the prices of animal feed ingredients

model (x, y)	Optimal lag	Akaike's $\mathrm{FPE}_X(Y)$ (1)	Null hypothesis: X not caused by Y calculated F statistic (2)	Long-run multipliers LM_{XY} (3)	Adjustment period (4)
(CAS, SOYB)	(1, 1)	23.124	0.983	*x*	*x*
(CAS, RAPE)	(1, 1)	23.004	2.508	*x*	*x*
(CAS, CGF)	(1, 17)	21.224	3.549^a	−0.004*	8
(CAS, SUNF)	(1, 3)	22.194	5.766^a	0.125*	2
(SOYB, RAPE)	(5, 10)	32.003	2.249^a	0.047**	17
(SOYB, CAS)	(5, 6)	31.891	2.612^a	−0.069**	13
(SOYB, CGF)	(5, 1)	32.409	1.120	*x*	*x*
(SOYB, SUNF)	(5, 1)	32.159	3.364^c	0.178***	5
(RAPE, SOYB)	(1, 1)	93.164	11.610^a	0.286	5
(RAPE, CAS)	(1, 2)	93.594	2.034	*x*	*x*
(RAPE, CGF)	(1, 1)	96.271	1.811	*x*	*x*
(RAPE, SUNF)	(1, 1)	94.611	6.968^a	0.302*	3
(CGF, SOYB)	(4, 4)	101.630	5.034^a	0.398*	8
(CGF, CAS)	(4, 7)	88.322	10.390^a	0.466*	9
(CGF, RAPE)	(4, 3)	103.780	3.936^a	0.126*	5
(CGF, SUNF)	(4, 2)	101.520	8.230^a	0.325*	6
(SUNF, SOYB)	(1, 4)	20.189	6.543^a	0.527*	5
(SUNF, RAPE)	(1, 1)	21.516	0.794	*x*	*x*
(SUNF, CGF)	(1, 6)	21.404	2.042^b	−0.002**	6
(SUNF, CAS)	(1, 2)	21.430	1.973	*x*	*x*

CAS, price of cassava, SOYB, price of soybean meal; RAPE, price of rapeseed meal; CGF, price of corn gluten feed; SUNF, price of sunflower meal.

* Rejection of the null hypothesis at the 1% significant level.

** Rejection of the null hypothesis at the 5% significant level.

*** Rejection of the null hypothesis at the 10% significant level.

(1) $\mathrm{FPE}_X(Y)$ is the value of the FPE corresponding to the optimal lag on variable Y in the equation for variable X.

(2) This column gives the calculated value of he Fisher statistic under the null hypothesis that the coefficients of the lags of variable Y in the X equation are zero.

(3) LM_{XY} is the long-run multiplier effect of variable Y on variable X. It is only presented when Y is found to cause X.

(4) Number of weeks needed for realization of 95% of the adjustment of X to a shock on Y.

TABLE 2

Model finally retained for the prices of feed ingredients at the end of the Caines – Keng and Sethi approach

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$$\begin{array}{l} \mathrm{CAS}_t \\ \mathrm{SOYB}_t \\ \\ \mathrm{RAPE}_t \\ \mathrm{SUNF}_t \\ \mathrm{CGF}_t \end{array} = \begin{array}{c} a_0 \\ b_0 \\ \\ c_0 \\ d_0 \\ e_0 \end{array} + \begin{array}{ccccc} a_1^1(L) & 0 & 0 & 0 & 0 \\ 0 & b_2^5(L) & 0 & 0 & 0 \\ \\ 0 & b_3^1(L) & b_3^1(L) & 0 & 0 \\ 0 & b_4^4(L) & 0 & d_4^1(L) & 0 \\ a_5^7(L) & a_5^4(L) & c_5^3(L) & d_5^2(L) & e_5^4(L) \end{array} \begin{array}{l} \mathrm{CAS}_t \\ \mathrm{SOYB}_t \\ \\ \mathrm{RAPE}_t \\ \mathrm{SUNF}_t \\ \mathrm{CGF}_t \end{array} + \begin{array}{l} u_t^{\mathrm{CAS}} \\ u_t^{\mathrm{SOYB}} \\ \\ u_t^{\mathrm{RAPE}} \\ u_t^{\mathrm{SUNF}} \\ u_t^{\mathrm{CGF}} \end{array}$$

Where $x_i^k(L)$ means that the order of the log polynomial $x_i(L)$ is k.