Modelling interrelated agricultural markets: the case of animal feed ingredients in the European Union

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MODELLING INTERRELATED AGRICULTURAL MARKETS: THE CASE OF ANIMAL FEED INGREDIENTS IN THE EUROPEAN UNION

by

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Abstract

This paper*describes a disaggregated econometric model of the EU/Benelux feed-livestock economy, reflecting the interrelationships between the various commodity markets involved. Specific features of the model are: (i) the use of flexible functional forms (i.e., the Asymmetric and Symmetric Generalised McFadden function) representing feed demand in the Benelux and the Rest-of-the-EU, and (ii) the incorporation of both price-induced and exogenous technical change. World prices of feed ingredients and prices of compound feeds are endogenised by market-clearing conditions. This model has been built for the purpose of quantifying the impact of changes in agricultural policies in the EU and the Uruguay Round commitments on the feed-livestock economy. Because all model components are specified in a dynamic fashion, it is possible to identify both short-term and long-term effects of the policy changes.

* This paper presents intermediate results of ongoing research. Any comments on this paper are welcomed by the authors.

1. INTRODUCTION

This paper describes the structure of a model which is built for the purpose of quantifying the implications of changes in agricultural policies in the European Union (EU) and the Uruguay Round commitments of the GATT for the EU feed-livestock economy. The model focusses primarily on the situation in Belgium and the Netherlands — i.e., two countries (members of the Benelux), where the feed-livestock sector is most sensitive to the well-known "cereal substitutes problem".

The model possesses the following special properties:

- The model is composed of several modules which are constructed using several approaches: for example, the econometric estimation of flexible functional forms is combined with the calibration of linear functions using a synthetic approach.
- The model is able to produce full and theoretically-consistent matrices of own- and cross-price elasticities of feed input demand for the Benelux and the Rest-of-the-EU (ROEU).
- The model incorporates both price-induced and exogenous technical innovation in the production of compound feed rations, as defined by Peeters (1995) and Peeters and Surry (1996).
- By exploiting the property of non-jointness (in input quantities), the model allows to identify both the allocation of feed ingredients between the various livestock categories and the composition of the different compound feed rations (Peeters and Surry 1993).
- World prices of major non-grain feed ingredients are determined endogenously by the model, whereas world prices for cereals and soymeal are taken from recent FAPRI projections — which also take into account supply-side developments in the major trading countries (FAPRI, 1995).
- All model components are specified in a dynamic fashion, which allows to identify both short-term and long-term effects of policy changes.
- In addition, all model components are calibrated to reproduce recent historical data (1985-1995) as closely as possible and to generate projections for the next eight years (1995-2003).

Models of the EU feed-livestock sector are not abundant; most studies analysing the implications of CAP reform and/or GATT are qualitative in nature or they were conducted at an aggregated level. Hence, this paper contributes to the scant literature on modelling the EU feed-livestock economy for quantitative policy analysis.

The Benelux countries are selected as a case study for several reasons: (i) the availability of sufficient relevant price and quantity data, (ii) the usage, in both countries, of a wide range of non-grain feed ingredients ("cereal substitutes"), and (iii) the importance of both countries, relative to the EU as a whole, with respect to the usage of major (marketable) feed ingredients. As a result of (ii) and (iii), the feed-livestock sectors in the Benelux are likely to be the most severely affected by the CAP reform as well as the Uruguay Round commitments relating to the "re-balancing" issue. To illustrate the relative importance of the Benelux, Table 1 shows the demand for marketable feed ingredients in the Benelux countries, relative to the EU-12 (for 1991). Obviously, 20% of total EU consumption of corn gluten feed (CGF) is accounted for by the Benelux countries. In the case of manioc, this proportion is even 53%. Also, nearly 20% of beet pulp and 22% of protein-rich feeds are used by the Benelux countries. On the other hand, the Benelux countries used only 4% of total EU feed demand for cereals.

The paper is organised as follows: Section 2 gives an overview of the general characteristics and the underlying assumptions of the model. In the Appendices, the formal structure of the empirical model is described more extensively. In the subsequent Sections 3 to 7, the various model components are described. In Section 8, preliminary validation results for the model are presented. Although the model described in this paper was designed to simulate two different policy scenarios (that is, a baseline scenario, on the one hand, and a GATT scenario, on the other hand), we are not able to report the corresponding simulation results due to some unexpected difficulties we encountered in running the model. This papers concludes by indicating areas of improvement and potential extensions, both in terms of model specifications and policy applications.

2. GENERAL MODEL CHARACTERISTICS AND ASSUMPTIONS

The model consists of four structural components, which appear in the following general equation:

$$D_{\text{Benelux}} + D_{\text{ROEU}} = S_{\text{EU}} + ES_{\text{ROW}} \tag{1}$$

where: D_{Benelux} is domestic demand for feed ingredients in the Benelux, D_{ROEU} is domestic demand for feed ingredients in the Rest-of-the-EU (ROEU), S_{EU} is domestic supply of feed ingredients in the EU, and ES_{ROW} is excess supply of feed ingredients in the Rest-of-the-World (ROW).

Each component of equation (1) is modelled differently. In other words, the model used to evaluate the GATT reform is composed of four different "blocks" or sub-models. In addition, demand for feed ingredients in the Benelux is mediated by a livestock supply system. In deriving the various structural equations of the model, a "mixed" approach is adopted. Explicit econometric models of demand (supply) are developed for the Benelux countries (EU countries); for convenience, the Rest-of-the-EU (ROEU) and the Rest-of-the-World (ROW) are modelled using a synthetic approach:

(i) Demand in the Benelux: disaggregated non-linear demand system, econometrically estimated using a non-joint SGM cost function approach (see Appendix 1);

(ii) Demand in the ROEU: disaggregated "almost" linear (Nerlovian) demand system based on a fully-consistent and complete elasticity matrix derived from a set of "informed" own-price elasticities and the application of the (implicit additivity) properties of the CDE functional form (see Appendix 2);

(iii) Supply in the EU and excess supply in the ROW: synthetic linear (Nerlovian) supply systems based on sets of "informed" elasticities (incomplete matrices), for selected (major) feed ingredients (see Appendix 3).

The model consists of about 250 equations and endogenous variables. The main exogenous variables are time trend, livestock supply, cereal policy prices and world prices of soymeal (and related products); recent FAPRI projections concerning macro-economic variables have

been used. World prices in the model are EU border prices expressed in a common currency, namely the Dutch guilder.

3. DEMAND FOR FEED INGREDIENTS IN THE BENELUX

In modelling demand equations for feed ingredients in the Benelux, a three-level cost minimisation procedure is adopted. The various feed ingredients and livestock feed rations considered as well as the structure of the aggregation (levels A, B, and C) employed in the model are shown in **Figure 1** (note that there are slight differences between Belgium and the Netherlands due to data availability). At the upper level A, demand relationships for aggregate feed inputs (cereals, cereal substitutes, protein feeds, additives) are estimated using a non-joint cost function (see Peeters and Surry, 1993, for more details on the implications of non-jointness). Hence, it is assumed that feed compounders decide on the composition of feed aggregates in order to minimise the cost of producing given levels of compound feed outputs. In addition, it is explicitly recognised that technical change, both endogenous (induced by past prices) and exogenous (represented through a linear time trend), gradually facilitates the displacement of relatively expensive cereals in the livestock feed rations (Peeters, 1995; Peeters and Surry, 1996). Finally, non-feed inputs, such as labour, energy, capital, packing materials, etc., are excluded from the analysis since they are assumed to be functionally separable from the feed inputs.

For the specification of the cost function, the Symmetric Generalised McFadden (SGM) form is chosen, which allows to impose concavity without destroying the (local) flexibility of the cost function (Diewert and Wales, 1987). Implicit in the aggregation is the assumption of weak separability, a necessary condition for consistent aggregation (see Peeters and Surry, 1994, for more details on the implications of weak separability). At the lower levels B and C, separate SGM and (in some cases) linear price functions (price indexes) for each feed aggregate are estimated. These price indexes, which enter as RHS variables (instruments) in the next upper level, allow us to derive the demand relationships for individual feed ingredients (maize, manioc, soymeal, animal meals, etc., for level B and brans, citrus pulp, etc., for level C). The formal structure of the Benelux demand models is given in **Appendix 1**. The models for

Belgium and the Netherlands are estimated independently; the econometric estimation is based on annual data for Belgium and the Netherlands, respectively, covering the period 1967-1991.

The resulting system of non-linear demand equations describes the quantities demanded for feed ingredients as functions of own prices and prices of substitute products. As was shown in Peeters and Surry (1993), the assumption of non-jointness (along with constant returns to scale) allows to derive the following structural information: (i) the compensated price elasticities of demand for feed components per livestock category, (ii) the allocation of feed ingredients to the various livestock categories (that is, complete feed utilization matrices), and (iii) the composition of each livestock feed ration.[1] Knowledge of the composition of each feed ration allows, in turn, to calculate the prices of the various livestock feed rations. It should be noted, however, that the assumption of weak separability has some restrictive implications for the demand for feed components; that is, the quantity of each feed component (say, maize or soymeal) varies in proportion to the quantity of the associated feed aggregate (cereals or high-protein feeds). Due to space limitations, the full elasticity and feed utilisation matrices are not reported here; they are available from the authors upon request.

4. DEMAND FOR FEED INGREDIENTS IN THE REST-OF-THE-EU

The system of demand functions for the individual feed ingredients in the Rest-of-the-EU (ROEU) has been constructed in two stages.

In the first stage, a full matrix of demand elasticities is derived from a set of prespecified ("informed") own-price demand elasticities. This procedure, which is described in more detail in **Appendix 2**, is based on the application of the (implicit additivity) properties of the CDE functional form (see Hanoch, 1975; Surry, 1993).[2]

In the second stage, input-output demand equations have been derived from an asymmetric McFadden cost function (with constant returns to scale), which are calibrated using the elasticities derived in the first stage.

5. SUPPLY OF FEED INGREDIENTS IN THE EU

A large number of feed ingredients which have been incorporated into the model are produced in the EU. Many of these domestic products, in particular those belonging to the category of "Other energy products", are by-products of the EU food-processing industry. This implies that the supply of these products is essentially price inelastic. As a result, many of the own-price supply elasticities were initially set at low values, ranging between 0.1 and 0.3. However, this caused several computational problems and/or unrealistic outcomes, so we decided to increase the values of the supply elasticities, ranging between 0.3 and 0.6.

For two particular feed ingredients, namely "Domestically-produced oilcakes" and "Other high protein feeds", the domestic supply is responding to the price of substitutes. For the former one, it is assumed that the the domestic supply responds to the price of soymeal. This is supposed to reflects the possibility for EU oilseeds crushers to substitute soybeans for domestically-produced oilseeds. The category of "Other high protein feeds" includes pulses, oilseeds and other protein-rich crops (feed peas for instance) whose production has expanded significiantly over the last twenty years. This stems from the fact that generous support was provided for these crops under the umbrella of the CAP. To capture the influence of the CAP, it was assumed the supply of other protein rich feed ingredients was responding to its own price and a price of a representative cereal crop substitute representative (maize). The price elasticities selected for other protein rich crops were taken from Beaudry (1994).

Table presents all the values selected for the supply price elasticities. Then, they serve to calibrate the domestic linear supply funtions over the period 1986-1991.

6. WORLD MARKET PRICES OF MAJOR FEED INGREDIENTS

Given the importance of the Benelux countries for major non-grain feed ingredients, the small-country assumption is not valid. Therefore, world market prices of feed ingredients, other than cereals and soymeal, are determined endogenously, through a system of interdependent (non-linear) demand and (linear) excess supply equations:

$$(D_{\text{Benelux}} + D_{\text{ROEU}}) - S_{\text{EU}} \equiv ED_{\text{EU}} = ES_{\text{ROW}} \qquad (2)$$

In other words, world equilibrium prices are established at the point where $ED_{\text{EU}} = ES_{\text{ROW}}$ relevant to the EU. The ED_{EU} equations are derived from the results obtained in the previous sections (D_{Benelux}, D_{ROEU}, and S_{EU}). The ES_{ROW} equations, on the other hand, are based on some strong assumptions with respect to demand-supply conditions in the Rest-of-the-World. A set of excess supply elasticities is calculated in terms of domestic demand and supply elasticities for major importing and exporting countries or regions, using a synthetic approach.[3] This method requires reliable information on the following items:

- world supply-demand balance sheets for each feed ingredient considered;
- supply and demand elasticities for the major exporters and importers, and
- price-transmission elasticities, reflecting the fact that EU domestic prices for some of the above-mentioned feed ingredients are somewhat insulated from world price effects (price margins and transport costs).[4]

Recall that world market prices of cereals, soymeal, and fats & oils are taken from available FAPRI projections, for the purpose of our convenience – given the complex nature of the world demand-supply conditions for these commodity markets and given the fact that endogenising these prices is far beyond the scope of our study. It should be acknowledged, though, that the FAPRI projections take into the major developments in the world markets for these products (including changes in the Eastern European countries).

Except for the EU cereal prices, domestic EU prices are linked to world market prices through price-linkage equations in which the degree of price transmission into the EU is defined. These price-linkage equations reflect bilateral exchange rates, transport, transfer-service margins, and policy-determined insulation of domestic prices from external market conditions. If no price transmission occurs, demand and supply (and trade) adjust only to internal conditions. The relevant elasticities are reported in Table A2.3.

7. DEMAND FOR COMPOUND FEEDS

The demand for compound feeds by livestock producers (Y) is specified as a linear function of the price of compound feeds relative to the price of livestock (PF/PL) and the level of livestock supply (L). A time trend (t) is also included in the compound feed demand function in a non-linear fashion, which is supposed to capture (i) the growing importance of compound feeds for livestock feeding in the Benelux, and (ii) the continued improvement in feeding efficiencies that will reduce the amount of feed required per livestock unit - i.e., the average feed conversion rate (Surry and Meilke, 1982). Specifically, these two developments are formally represented by assuming that the marginal response of the demand for compound feeds w.r.t. livestock production — i.e., the coefficient $a_2(t)$ in the function below — has the form of a time-dependent S-shape. Such a specification allows $a_2(t)$ to vary from a low value $a_2(0)$ (i.e., a situation where livestock producers use almost no compound feeds) to a high value $a_2(1)$ (i.e., a situation where the total feed ration is made up of compound feeds). A Weibull functional form is selected to represent the S-shape (Sharif and Islam, 1980). This yields the following demand function for compound feeds (where α and β are the scale and shape parameters of the Weibull function, respectively):

$$y_{kt} = a_0 + a_1\left(\frac{PF_{kt}}{PL_{kt}}\right) + a_2(t)L_{kt} \tag{3}$$

where

$$a_2(t) = a_2(0) + a_2(1)\left[1 - \exp\left(\frac{t}{\alpha}\right)^{\beta}\right] \tag{4}$$

8. MODEL VALIDATION

The model was tested through running an historical dynamic simulation for the period 1986-1991. The results of this simulation (mean values) are reported in Table 2 (for the prices and quantities of the various feed ingredients) and Table 3 (for the prices and quantities of the various compound feeds).

Overall, the performance of the model in reproducing the historical values is quite satisfactory and promising. However, further work is still needed to improve the performance of the model.

9. CONCLUSION AND WORK IN PROGRESS

The model described above was intended for the purpose of policy simulation. We envisaged two different policy scenarios (assuming identical macro-economic and technical conditions):

(i) a baseline scenario that incorporates CAP reform in the EU, PROCAMPO in Mexico, the Blair House oilseeds agreement, NAFTA, and existing policies in other major trading countries;

(ii) a GATT scenario that incorporates the proposed changes in the agricultural policies of major trading countries resulting from GATT (assuming no increases in income above baseline levels).

To quantify the impact of GATT agreement on the EU (Benelux) feed-livestock economy, the model would have to be solved under these two alternative scenarios for the period 1995-2003. A comparison of the results (w.r.t. several prices and quantities) of the baseline and the GATT scenarios in each simulated year would give a dynamic representation of the impacts of the proposed changes in agricultural policies.

Unfortunately, however, we were not able at this point in time to fully run the simulations, due to unexpected computational difficulties. But this is just a matter of time. We hope to be able to conduct the envisaged simulations very soon.

Nonetheless, we are convinced that the dynamic model described in this paper is a useful tool for this type of policy analysis. The outcomes of this analysis might give some indications of how the feed-livestock sectors of the Benelux countries would be affected throughout the 1990s by the proposed CAP reforms.

Several analytical questions still remain unanswered, however. Many key parameters of the model (in particular, the Benelux demand elasticities) are grounded on a strong empirical basis

and therefore their values are judged to approximate their "true" values. Other parameters, however, notably the ROW excess supply elasticities and ROEU import demand elasticities, lack this empirical basis. Therefore, examining the robustness of the simulation results to changes in these parameters would be desirable. Although it is recognised that sensitivity analysis with respect to the values assigned to all model parameters (and especially those determined exogenously) is an important element in any policy modelling, no analysis of this issue has been undertaken here. Further elaboration of the model and simulation of updated CAP reform scenarios are currently undertaken by the authors.

Table 1. Demand for marketable feed ingredients in the Benelux and the EU (1991)

Feed ingredient	EU-12	Belgium	Netherlands	Benelux	EU-12
	(1000 t)	----------	(% of EU-12	----------	
Cereals	83301	1.4	2.9	4.2	100.0
- Maize	20800	1.4	3.9	5.4	100.0
- Barley	30300	1.0	2.5	3.4	100.0
- Wheat	23900	2.3	3.0	5.3	100.0
- Other cereals	8301	0.9	1.6	2.5	100.0
Energy feeds	29700	5.1	19.7	24.8	100.0
- Molasses	4500	4.5	18.6	23.1	100.0
- Manioc	5800	9.8	43.4	53.2	100.0
- Brans	10600	1.1	9.8	10.9	100.0
- Fats & oils	1400	8.3	35.3	43.6	100.0
- Citrus pulp	1600	3.6	16.0	19.6	100.0
- Beet pulp	5800	7.8	12.2	19.9	100.0
Protein feeds	45463	5.2	16.8	22.0	100.0
- Animal meals	3200	5.9	15.9	21.8	100.0
- Pulses	9400	7.2	18.9	26.1	100.0
- Corn gluten feed	7700	4.4	18.0	22.4	100.0
- Soymeal	12445	2.6	11.8	14.4	100.0
- Domestic oilcakes	9290	3.5	15.8	19.3	100.0
- Tropical oilcakes	3428	4.2	25.3	29.6	100.0
TOTAL	158464	3.2	10.0	13.2	100.0

Source: EUROSTAT, Feed Supply Balance Sheets.

Figure 1 — Commodity coverage and aggregation of feed ingredients

BELGIUM				
Level A	**Cereals**	**Energy feeds**	**Protein feeds**	Additives
Level B	-Maize -Barley -Sorghum -Wheat & Other cereals	-Molasses -Manioc **-By-products** -Fats & oils	-Animal meals -Pulses & dried products -Proteins -25% (incl. CGF) **-Proteins +25%**	
Level C		-Beet pulp -Citrus pulp -Brans	-Soymeal -Domestically-produced oilcakes -Tropical oilcakes	
NETHERLANDS				
Level A	**Cereals**	**Energy feeds**	**Protein feeds**	Additives
Level B	-Maize -Barley -Other cereals -Wheat	-Molasses -Manioc -Brans **-Pulp**	-Animal meals -Other protein feeds -Corn gluten feed **-Oilcakes**	
Level C		-Beet pulp -Citrus pulp	-Soymeal -Domestically-produced oilcakes -Tropical oilcakes	
ROEU				
Level A	**Cereals**	**Energy feeds**	**Protein feeds**	n.a..
Level B	-Maize -Barley -Other cereals -Wheat	-Molasses -Manioc -Brans **-Pulp**	-Animal meals -Other protein feeds -Corn gluten feed **-Oilcakes**	
Level C		-Beet pulp -Citrus pulp	-Soymeal -Domestically-produced oilcakes -Tropical oilcakes	

Note: For an exact definition of the feed categories, see Peeters and Surry (1993b).

Table 2 — Results of the historical dynamic simulation 1986-1991 for feed ingredients (average values)

Commodity	Mean simulated values	Mean observed values	Mean percentage errors
Quantities (1000 tonnes)			
BELGIUM			
Cereals	1360.0	1242.2	9.5
Energy feeds	1565.0	1585.8	-1.3
Protein feeds	2316.4	2127.7	8.9
Additives	188.4	284.2	-33.7
NETHERLANDS			
Cereals	2162.5	2175.3	-0.6
Energy feeds	6619.2	5917.8	11.9
Protein feeds	8361.7	7842.8	6.6
Additives	345.5	393.6	-12.2
ROEU			
Cereals	79893.3	73882.0	8.1
Energy feeds	18448.5	21896.3	-15.7
Protein feeds	38837.0	38957.3	-0.3
Prices (ECU/ton)			
ROW			
Molasses	72.6	71.8	1.2
Manioc	162.5	156.0	4.1
Fats & oils	352.2	352.3	-0.0
Beet pulp	360.5	140.4	156.8
Animal meals	352.2	359.4	-2.0
Pulses	112.8	112.8	0.0
Corn gluten feed	144.4	141.3	2.2
Dom-prod oilcakes	153.9	153.9	0.0
Tropical oilcakes	147.1	143.8	2.3

Table 3 — Results of the historical dynamic simulation 1986-1991 for compound feeds (average values)

Commodity	Mean simulated values	Mean observed values	Mean percentage errors
Quantities (1000 tonnes)			
BELGIUM			
Feed for broilers	649.9	642.7	1.1
Feed for layers	397.7	374.8	6.1
Feed for pigs	2964.8	2859.5	3.7
Feed for beef	538.5	623.8	-13.7
Feed for dairy	530.2	526.4	0.7
NETHERLANDS			
Feed for poultry	3446.3	3358.9	2.6
Feed for pigs	7764.7	7608.2	2.1
Feed for cattle	4819.2	4347.2	10.9
Prices (BEF per tonne in Belgium; HFL per tonne in the Netherlands)			
BELGIUM			
Feed for poultry	8.8	8.7	1.4
Feed for pigs	21.5	21.4	0.8
Feed for cattle	7.7	7.6	1.8
NETHERLANDS			
Feed for poultry	1.4	1.4	1.2
Feed for pigs	2.6	2.6	0.3
Feed for cattle	1.7	1.7	1.6

Appendix 1: Formal structure of the empirical model

In specifying the empirical model, following the three-level approach (see Figure 1), we use the Symmetric Generalised McFadden (SGM) functional form, introduced by Diewert and Wales (1987). Inspiration was also found in Kohli (1993) and Lawrence (1989), among others, for the specification of the upper level A, on the one hand, and the lower levels B and C, on the other hand. For the incorporation of price-induced technological change, we follow the procedure suggested by Lasserre and Ouellette (1991) and applied by Peeters (1995).

We adopt the following notation: n is the number of feed inputs (either the number of feed aggregates at level A or the number of feed components per feed aggregate at levels B and C); m is the number of compound feed outputs (only level A); $a \equiv [a_i]$ is an $n \times 1$ column vector of unknown parameters, $\alpha_T \equiv [\alpha_{iT}]$ is an $n \times 1$ column vector of unknown parameters, $\beta_T \equiv [\beta_{kT}]$ is an $k \times 1$ column vector of unknown parameters, γ_t and γ_{tt} are unknown scalars, $B \equiv [b_{ij}]$ is an $n \times n$ matrix of unknown parameters, $C \equiv [c_{kh}]$ is an $n \times m$ matrix of unknown parameters, $A \equiv [\alpha_{ij}]$ is an $n \times n$ matrix of unknown parameters, w is an $n \times 1$ column vector of (observed) input prices of individual feed components at levels B and C (indexed i,j), p is an $n \times 1$ column vector of (computed) input prices of feed aggregates at level A (indexed i,j), z is an $n \times 1$ column vector of (observed) input quantities of individual feed components at levels B and C (indexed i,j), x is an $n \times 1$ column vector of (observed) input quantities of feed aggregates at level A (indexed i,j), y is an $m \times 1$ column vector of observed output quantities (indexed k,h), θ is an $n \times 1$ column vector of predetermined parameters, ψ is an $m \times 1$ column vector of predetermined parameters. To keep the notation simple, we use the same subscripts as well as the same set of parameters (either unknown or predetermined) for the three aggregation levels A, B, and C, in Figure 1.

Level A — At the upper aggregation level A, we specify a fully flexible, non-joint, SGM cost function:

$$C_t(\bullet) = \tfrac{1}{2}\left(\frac{p_t^T B p_t}{\theta^T p_t}\right)(\psi^T y_t) + p_t^T C y_t + \sum_{i=1}^{n} \Phi^i(\bullet) p_{it}(\psi^T y_t)$$

$$+ \sum_{k=1}^{m} (\beta_{kT} t) y_{kt}(\theta^T p_t) + (\theta^T p_t)(\psi^T y_t)\gamma_t t + \tfrac{1}{2}(\theta^T p_t)(\psi^T y_t)\gamma_{tt} t^2 \qquad \text{(A1.1)}$$

where

$$\Phi^i(\bullet) = \sum_{j=1}^{n} \frac{\alpha_{ij}}{1-\lambda L}\left(\frac{p_{jt-1}}{\theta^T p_{t-1}}\right) + \alpha_{iT} t, \quad \text{for } i = 1,\ldots,n \qquad \text{(A1.2)}$$

The cost function in (A1.1) is an augmented version of the (profit function) specification suggested by Kohli (1993), due to the lagged prices which are allowed to interact with the input prices (geometrically-declining lag structure) and the usual integer measure of time. The additional term $\Phi^i(\bullet)$ is introduced to represent both endogenous (price-induced) and exogenous changes in the feed mixing technology (i.e., structural shifts in the composition of livestock feed rations). The implications of non-jointness in (feed) input quantities (NJIQ) are described in Peeters and Surry (1993). Apart from the symmetry conditions imposed on the matrices $A \equiv [\alpha_{ij}]$ and $B \equiv [b_{ij}]$, the following parameter restrictions are required: $\Sigma\alpha_{ij} = 0$, $\Sigma b_{ij} = 0$, $\Sigma\alpha_{iT} = 0$, $\Sigma\beta_{kT} = 0$, $\Sigma\theta_i = 1$, and $\Sigma\psi_k = 1$. The inner products $\theta^T p_t$ and $\psi^T y_t$ can be interpreted as fixed-weight price and quantity indexes, where θ_i and ψ_k denote the cost share of input i and the value share of output k, respectively. Note that at the upper level A, input prices represent the price indexes of feed aggregates (cereals, cereal substitutes, protein feeds, and additives), while output quantities refer to the various livestock feed rations or compounds (for poultry, pigs, and cattle).

Application of Hotelling's lemma, while normalizing the demand for feed aggregates by using the aggregate output quantity index, $\psi^T y_t$, yields the following:

$$\frac{x_{it}}{\psi^T y_t} = \frac{B_i p_t}{\theta^T p_t} - \tfrac{1}{2}\theta_i \frac{p_t^T B p_t}{(\theta^T p_t)^2} + \frac{C_i y_t}{\psi^T y_t} + \Phi^i(\bullet)$$

$$+ \frac{\theta_i}{\psi^T y_t}\left(\sum_{k=1}^{m} (\beta_{kT} t) y_{kt}\right) + \theta_i \gamma_t t + \tfrac{1}{2}\theta_i \gamma_{tt} t^2, \quad \text{for } i = 1,\ldots,n \qquad \text{(A1.3)}$$

where B_i and C denote the i-th row of the matrices B and C, respectively. From this expression, it is clear that the term $\Phi^i(\bullet)$ represents a simple 'shifter' (Lasserre and Ouellette, 1991) of the (normalized) aggregate feed input demand. Note that the free parameters α_{iT} in $\Phi^i(\bullet)$ are input-specific, whereas the γ_t and γ_{tt} are common (unknown) scalars; so, there is no redundancy in the system.

By replacing the term $\Phi^i(\bullet)$ in (A1.3) by the RHS of (A1.2), and using a Koyck transformation with constant adjustment parameter λ, we obtain (for $i = 1,\ldots,n$) the following expression:

$$\begin{aligned}\frac{x_{it}}{\psi^T y_t} &= B_i\left(\frac{p_t}{\theta^T p_t} - \lambda\frac{p_{t-1}}{\theta^T p_{t-1}}\right) - \tfrac{1}{2}\theta_i\left(\frac{p_t^T B p_t}{(\theta^T p_t)^2} - \lambda\frac{p_{t-1}^T B p_{t-1}}{(\theta^T p_{t-1})^2}\right)\\ &\quad + C_i\left(\frac{y_t}{\psi^T y_t} - \lambda\frac{y_{t-1}}{\psi^T y_{t-1}}\right) + \frac{A_i p_{t-1}}{\theta^T p_{t-1}} + \alpha_{iT}(t - \lambda(t-1))\\ &\quad + \theta_i\left(\sum_k(\beta_{kt}t)\frac{y_{kt}}{\psi^T y_t} + \gamma_t t + \tfrac{1}{2}\gamma_{tt}t^2\right.\\ &\quad \left. - \lambda\sum_k(\beta_{kT}(t-1))\frac{y_{k,t-1}}{\psi^T y_{t-1}} - \lambda\gamma_t(t-1) - \tfrac{1}{2}\lambda\gamma_{tt}(t-1)^2\right) + \lambda\frac{x_{it-1}}{\psi^T y_{t-1}}\end{aligned} \qquad \text{(A1.4)}$$

where A_i denotes the i-th row of matrix A. Using (A1.3) and (A1.4), the technical change term $\Phi^i(\bullet)$ can be written alternatively as

$$\Phi^i(\bullet) = \frac{A_i p_{t-1}}{\theta^T p_{t-1}} + \alpha_{iT}t + \{\text{lagged terms in Eq.(A1.4)}\}, \qquad \text{for } i = 1,\ldots,n \qquad \text{(A1.5)}$$

This last expression can now be inserted into the marginal (unit) feed cost equations, which then looks as follows:

$$\begin{aligned}g_{kt} &= \tfrac{1}{2}\psi_k\left(\frac{p_t^T B p_t}{\theta^T p_t}\right) + p_t^T C_k + \psi_k\left(\sum_{i=1}^{n}\Phi^i(\bullet)p_{it}\right)\\ &\quad + (\theta^T p_t)\beta_{kT}t + \psi_k(\theta^T p_t)\gamma_t t + \tfrac{1}{2}\psi_k(\theta^T p)\gamma_{tt}t^2, \qquad \text{for } k = 1,\ldots,m\end{aligned} \qquad \text{(A1.6)}$$

where C_k is the k-th column of matrix C, and g_k is defined as in Peeters and Surry (1993). Note that the marginal (unit) feed cost, g_k , is not observable, whereas the price of each compound feed output, PF_k, is observable. Assuming constant price margins for each livestock-specific compound, we assume the following relationship between g_k and PF_k:

$$g_k = (1 - \delta)PF_k \tag{A1.7}$$

where δ denotes the share of non-feed costs in total production costs.

The input prices used at the upper-level estimation are the price indexes derived from the lower-level price function estimates, which will be described next.

Levels B and C — At the lower aggregation levels B and C, we use the following SGM price function (single-output unit cost function):

$$p_t(\bullet) = a^T w_t + \tfrac{1}{2}\left(\frac{w_t^T B w_t}{\theta^T w_t}\right) + \sum_{i=1}^{n} \Phi^i(\bullet) w_{it} \tag{A1.8}$$

The price function in (A1.8) is a modified version of the price function specification suggested by Lawrence (1989), where the term $\Phi^i(\bullet)$, which is introduced to represent both endogenous (price-induced) and exogenous technical changes, is defined as in (A1.2). Apart from the symmetry conditions imposed on the matrices $A \equiv [\alpha_{ij}]$ and $B \equiv [b_{ij}]$, the following parameter restrictions are required: $\Sigma\alpha_{ij} = 0$, $\Sigma b_{ij} = 0$, and $\Sigma\theta = 1$. The inner product $\theta^T w$ can be interpreted as a fixed-weight price index, where θ_i denotes the cost share of feed component i from the feed aggregate under consideration. Note that at aggregation level B, input prices and quantities refer to the individual cereal, substitute, and protein components, whereas at aggregation level C, they refer to the individual oilcake, by-product, and pulp components (consequently, p_t and x_t are replaced by w_t and z_t, respectively).

Application of Shephard's lemma, while normalizing the demand for feed components using a divisia quantity index of the corresponding feed aggregate, x_t, yields the following:

$$\frac{z_{it}}{x_t} = a_i + \frac{B_i w_t}{\theta^T w_t} - \tfrac{1}{2}\theta_i \frac{w_t^T B w_t}{(\theta^T w_t)^2} + \Phi^i(\bullet), \qquad \text{for all } i \tag{A1.9}$$

where B_i is the i-th row of matrix B. Using again a Koyck transformation, with constant adjustment parameter λ, (A1.9) can be rewritten as follows:

$$\frac{z_{it}}{x_t} = (1-\lambda)a_i + B_i\left(\frac{w_t}{\theta^T w_t} - \lambda\frac{w_{t-1}}{\theta^T w_{t-1}}\right) - \tfrac{1}{2}\theta_i\left(\frac{w_t^T B w_t}{(\theta^T w_t)^2} - \lambda\frac{w_{t-1}^T B w_{t-1}}{(\theta^T w_{t-1})^2}\right)$$
$$+ \frac{A_i w_{t-1}}{\theta^T w_{t-1}} + \alpha_{iT} t - \lambda\alpha_{iT}(t-1) + \lambda\frac{z_{it-1}}{x_{t-1}}, \qquad \text{for all } i \tag{A1.10}$$

Using (A1.9) and (A1.10), the technological change term $\Phi^i(\bullet)$ for the lower level can be written alternatively as

$$\Phi^i(\bullet) = \frac{A_i w_{t-1}}{\theta^T w_{t-1}} + \alpha_{iT} t + \left\{-\lambda a_i + \text{lagged terms in Eq.(A1.10)}\right\}, \qquad \text{for all } i \tag{A1.11}$$

Appendix 2 : Assembling the simulation model

Demand of the Benelux versus the ROEU — For Belgium/the Netherlands, we use SGM-based demand equations for all feed components, including cereals (as described in Appendix 1). For the ROEU, we use linear demand equations for all feed ingredients except cereals, where technological change is reflected through a Nerlovian specification (partial adjustment). Demand equations for cereals are not considered here, since our focus is on the demand for cereals in the Benelux, while we assume at the same time policy-determined (exogenous) EU prices for cereals. The parameters of the linear demand equations in the ROEU are derived from a full matrix of CDE-based demand elasticities (see Table A2.1). These elasticities are calibrated to the "base-period" price/quantity observations (i.e., the mean observations over the period 1986-1990), where we use dummy variables to account for annual shifts, for each separate feed component. In developing the CDE-based elasticities for the ROEU, we adopt a similar three-stage method as for Belgium and The Netherlands. A more detailed description of the underlying principles of the CDE procedure is given in Appendix 3.

Supply of the EU-12 — For the EU-12 as a whole (Benelux plus EU-9), we use linear supply equations for all non-grain feed components, except for manioc, citrus pulp, and tropical oilcakes (for which no positive supply exists in the EU-12), based on a predetermined set of (mostly direct) price elasticities (see Table A2.2). In general, low supply elasticities are used to reflect the fact that most of these feed components are simply by-products of other industrial activities.

Excess supply of the ROW — For the ROW, we use linear excess-supply equations for all non-grain feed components, based on two separate sets of elasticities (diagonal or incomplete matrices of elasticities, containing only a limited number of off-diagonal elements, depending on the type of feed component)—one for demand of the ROW, and one for supply of the ROW (see Table A2.3). Excess supply elasticities for the ROW are derived using the formula described in Surry (1988, Annex 7) and Meilke & De Gorter (...). No cross effects are considered for manioc, CGF, and other cereal substitutes; selected cross effects are considered

for oilcakes. Absence of cross effects is assumed between cereal substitutes and protein feeds (feed aggregates). This rather *ad hoc* approach is adopted due to several data limitations.

Reconciling price/quantity data — All prices in the model are converted into an index form. The Rotterdam prices are the leading prices (driving forces) for the ROEU. [This conversion will only affect the value of the constant terms in calibrating the linear demand functions for the ROEU.] The (indexed) Rotterdam prices are converted into Belgian prices using the results from a (linear) regression of Belgian prices to Dutch prices (adjusted for the HFL/BEF exchange rate)—to refect regional price differences (transportation costs). It should be noted, though, that Belgian prices are on a calendar-year basis, whereas Dutch (Rotterdam) prices are on a crop-year basis. Hence, we adopt the following rule: crop year 1987/88, say, corresponds to calendar year 1987, etc. The crop-year/calendar-year problem also exists for the quantities (domestic EU supply, EU imports and exports, from which we can derive excess demand of the ROEU): quantities of oilcakes are on a crop-year basis (Toepfer), whereas quantities of cereal substitutes are on a calendar-year basis. The latter are converted to a crop-year basis by taking the average of two consecutive calendar years. For example, the crop-year quantity for 1987/88 is calculated as the sum of the quantities for the calendar years 1987 and 1988, divided by two. Thus, quantities in the Netherlands, the ROEU, and the ROW are expressed on a crop-year basis. The Belgian quantity data are expressed on a calendar-year basis.

Establishing the benchmark equilibrium — In the calibration process, we have to ensure that an equilibrium relationship is satisfied in the base period ($ED_{EU} = ES_{ROW}$). Due to the existing inconsistencies of the various data sources, we have to define a residual category. We decided to use the observed quantities for Belgium, the Netherlands, and the ROW; hence, we calculated the ROEU demand quantities residually. In summary: $D_{Benelux}$, S_{EU}, and ES_{ROW} are observed, whereas D_{ROEU} is calculated residually.

Table A2.1 — CDE-based demand elasticities for the ROEU

	Maize	Barley	Other Cereals	Wheat	Molasses	Manioc	Brans	Fats & oils	Citrus pulp	Sugar beet	Animal meals	Pulses	Corn Gluten	Soymeal	Domestic oilcakes	Tropical oilcakes
Maize	-0.3579	0.0105	0.0536	0.0937	0.0046	0.0093	0.0270	0.0058	0.0125	0.0032	0.0192	0.0125	0.0162	0.0643	0.0191	0.0062
Barley	0.0086	-0.3707	0.0573	0.1049	0.0046	0.0093	0.0270	0.0058	0.0125	0.0032	0.0192	0.0125	0.0162	0.0643	0.0191	0.0062
Other cereals	0.1764	0.2302	-0.8676	0.2610	0.0046	0.0093	0.0270	0.0058	0.0125	0.0032	0.0192	0.0125	0.0162	0.0643	0.0191	0.0062
Wheat	0.1008	0.1378	0.0853	-0.5238	0.0046	0.0093	0.0270	0.0058	0.0125	0.0032	0.0192	0.0125	0.0162	0.0643	0.0191	0.0062
Molasses	0.0926	0.1131	0.0281	0.0861	-0.4296	0.0219	0.0863	-0.0255	-0.0423	-0.0108	0.0112	0.0073	0.0095	0.0375	0.0111	0.0036
Manioc	0.0926	0.1131	0.0281	0.0861	0.0109	-0.5595	0.1651	-0.0085	-0.0069	-0.0016	0 0112	0.0073	0.0095	0.0375	0.0111	0.0036
Brans	0.0926	0.1131	0.0281	0.0861	0.0148	0.0568	-0.4730	-0.0036	0.0040	0.0010	0.0112	0.0073	0.0095	0.0375	0.0111	0.0036
Fats & oils	0.0926	0.1131	0.0281	0.0861	-0.0202	-0.0136	-0.0168	-0.2373	-0.0893	-0.0280	0.0112	0.0073	0.0095	0.0375	0.0111	0.0036
Citrus pulp	0.0926	0.1131	0.0281	0.0861	-0.0154	-0.0038	0.0115	-0.0416	-0.2793	-0.0713	0.0112	0.0073	0.0095	0.0375	0.0111	0.0036
Sugar beet	0.0926	0.1131	0.0281	0.0861	-0.0154	-0.0038	0.0115	-0.0416	-0.2793	-0.0713	0.0112	0.0073	0.0095	0.0375	0.0111	0.0036
Animal meals	0.0909	0.1111	0.0276	0.0846	0.0026	0.0053	0.0155	0.0033	0.0072	0.0018	-0.7988	0.0659	0.0885	0.2122	0.0620	0.0202
Pulses	0.0909	0.1111	0.0276	0.0846	0.0026	0.0053	0.0155	0.0033	0.0072	0.0018	0.1013	-0.5317	0.0422	0.0275	0.0082	0.0026
Corn gluten	0.0909	0.1111	0.0276	0.0846	0.0026	0.0053	0.0155	0.0033	0.0072	0.0018	0.1047	0.0324	-0.5413	0.0390	0.0116	0.0036
Soymeal	0.0909	0.1111	0.0276	0.0846	0.0026	0.0053	0.0155	0.0033	0.0072	0.0018	0.0630	0.0053	0.0098	-0.5075	0.0497	0.0297
Dom. oilcakes	0.0909	0.1111	0.0276	0.0846	0.0026	0.0053	0.0155	0.0033	0.0072	0.0018	0.0630	0.0053	0.0098	0.1676	-0.6412	0.0455
Trop. oilcakes	0.0909	0.1111	0.0276	0.0846	0.0026	0.0053	0.0155	0.0033	0.0072	0.0018	0.0630	0.0053	0.0098	0.3104	0.1409	-0.8793

Table A2.2 — Supply elasticities for the EU

	Direct price elasticity	Elasticity w.r.t. price of oilcakes
Molasses	0.4	
Brans	0.7	
Fats & oils	0.4	
Beet pulp	0.4	
Animal meals	0.4	
Corn gluten feed	0.5	
Soymeal	0.6	
Domestic oilcakes	0.5	-0.25
Additives	0.6	

Table A2.3 — Excess supply elasticities for the ROW

	Direct price elasticities	Cross-price elasticities		
		Pulses	Soymeal	Domestically-produced oilcakes
Molasses	0.5			
Manioc	0.45			
Brans	0.1			
Fats & oils	0.3			
Citrus pulp	0.3			
Beet pulp	0.5			
Animal meals	1.0		-0.7	
Pulses	2.0		-0.7	-0.3
Corn gluten feed	0.3			
Domestically-produced oilcakes	2.0	-0.7	-0.7	
Tropical oilcakes	5.0		-0.25	

APPENDIX 3 : DEMAND ELASTICITIES FOR THE ROEU

A complete matrix of own- and cross-price demand elasticities for the ROEU is constructed using only *a priori* knowledge of the diagonal elements (own-price elasticities). The latter can be retrieved from the literature or derived from 'informed' estimates. For more details, see Surry (1993) and Hertel *et al.* (1991), among others.

The elasticities (ϵ_{ij}) associated with the CDE functional form are as follows:

$$\epsilon_{ij} = \sigma_{ij} s_j = \left(\alpha_i + \alpha_j - \sum_{k=1}^{n} s_k \alpha_k - \delta_{ij} \frac{\alpha_i}{s_i} \right) s_j, \qquad \text{for all } i,j \tag{A2.1}$$

where the α_i's denote the 'substitution parameters', the s_i's are the expenditure shares, and $\delta_{ii} = 1$, $\delta_{ij} = 0$ for $i \neq j$ (Kronecker delta). Note that the difference between the Allen elasticities of substitution, $\sigma_{ik} - \sigma_{jk}$, is constant (that is, invariant to k), hence the name CDE.

The expressions for the own-price elasticities (ϵ_{ii}) can be rewritten as follows:

$$\begin{aligned} \epsilon_{ii} &= 2\alpha_i s_i - s_i \sum_{k=1}^{n} s_k \alpha_k - \alpha_i \\ &= -\alpha_i (1 - s_i)^2 - s_i \sum_{k \neq i}^{n} s_k \alpha_k , \qquad \text{for } i = 1,\ldots,n \end{aligned} \tag{A2.2}$$

It is easy to see that all the α_i's (substitution parameters) can be derived from extraneously determined ϵ_{ii}'s (own-price elasticities) and observed s_i's (expenditure/revenue shares):

$$\begin{pmatrix} \alpha_1 \\ \alpha_2 \\ \cdot \\ \cdot \\ \cdot \\ \alpha_n \end{pmatrix} = - \begin{pmatrix} (1-s_1)^2 & s_1 s_2 & \cdots & s_1 s_n \\ s_1 s_2 & (1-s_2)^2 & \cdots & s_2 s_n \\ \cdot & \cdot & \cdot & \cdot \\ \cdot & \cdot & \cdot & \cdot \\ \cdot & \cdot & \cdot & \cdot \\ s_1 s_n & s_2 s_n & \cdots & (1-s_n)^2 \end{pmatrix}^{-1} \times \begin{pmatrix} \epsilon_{11} \\ \epsilon_{22} \\ \cdot \\ \cdot \\ \cdot \\ \epsilon_{nn} \end{pmatrix} \tag{A2.3}$$

After having calculated the α_i's, we can obtain all the remaining (off-diagonal) elements (ϵ_{ij} for $i \neq j$) of the elasticity matrices.

APPENDIX 4 : ECONOMETRIC ESTIMATION PROCEDURE

To estimate the demand systems for the three levels (A, B, and C) of the aggregation structure described in Figure 1, we use the standard TSP computer package (Version 4.3). All the demand systems are estimated using the iterative Zellner procedure (ITZEL), which is asymptotically equivalent to Full Information Maximum Likelihood (FIML). To preserve consistency throughout the three-level parameter estimation, the price indexes estimated at the lower levels B or C are used as instrumental variables (price instruments) at the next upper levels (see also Peeters and Surry, 1994). In addition, to ensure global concavity of the cost/price functions, attempts have been made to impose non-negativity constraints on the Cholesky values of the matrices A and B. In some instances, this procedure resulted in near zeros and insignificant estimates (a well-known result!); in other instances, estimation turned out to be infeasible (using TSP) due to non-convergence. Given the fact that the remaining parameter estimates were not particularly sensitive to the non-negativity constraints, as we could observe in preliminary estimations, we decided to set the Cholesky values with incorrect sign (that is, those that were positive in the unconstrained estimation) equal to zero.

In implementing the estimation of the demand systems at the various levels of the aggregation structure (levels A, B, and C in Figure 1), we used separate approaches.

Level A — For estimation purposes, the feed input demand equations in (A1.3) and the marginal feed cost equations in (A1.6) are expressed in nominal value terms—through multiplying both sides of the equations by the corresponding feed input price index and output quantity index. Thus, the dependent variables are: $R_i = x_i p_i$ ($i = 1,\ldots,n$) and $R_k = g_k y_k$ ($k = 1,\ldots,m$), where the subscripts i and k identify the various input and output aggregates, respectively. To avoid singularity, one of the equations must be dropped in the estimation procedure. The estimates are invariant to the equation deleted (see also Peeters and Surry, 1993).

Level B — To estimate the demand systems for the individual feed components, the specification of the demand equations remains the same as in (A1.9); that is, expressed in

terms of input-output ratios (where "output quantity" refers to the quantity of the corresponding feed aggregate). Thus, the dependent variables are: z_{ij}/x_j ($i = 1,\ldots,n$), where the subscript i identifies the various feed components per feed aggregate. Because there is no linear dependency in the system, all the equations must be estimated simultaneously.

Level C — For "oilcakes" (Belgium/the Netherlands), "by-products" (Belgium), and "pulp" (the Netherlands), we go one step further down the aggregation structure. Both SGM and linear specifications for the price functions are being used, depending on the feasibility of econometric estimation (data limitations). For "oilcakes" we use SGM price functions allowing for substitution, whereas for "by-products" and "pulp" we use linear price functions reflecting a Leontief technology (fixed "input-output" ratios). It should be noted that for Belgium no consistent price and quantity data are available at this level. Hence, we decided to use Dutch (Rotterdam) prices converted into BEF, along with quantity data from EUROSTAT ("Feed Balances"). Since the EUROSTAT data are published on a crop-year basis, they are not consistent with the data from BEMEFA, which are published on a calendar-year basis. In order to maximise consistency, we adopt the following (admittedly *ad hoc*) procedure. First, we construct SGM or linear price aggregators using Dutch prices and EUROSTAT quantities. Second, we fit linear regressions between the observed aggregate price indexes in Belgium (available from BEMEFA) and the estimated SGM (oilcakes) and linear (by-products) price indexes based on Dutch prices and EUROSTAT quantities:

$$\hat{p}^{B}_{CAK} = \alpha + \beta \cdot \hat{p}^{NL}_{CAK}, \quad \text{for oilcakes} \tag{A4.1}$$

and

$$\hat{p}^{B}_{BYP} = \alpha + \beta \cdot \hat{p}^{NL}_{BYP} = \alpha + \beta\left(\sum_i \mu_i w_i^{NL}\right), \quad \text{for by-products} \tag{A4.2}$$

In expression (A4.2), the μ_i's represent fixed input-output ratios (input quantities per unit of output) for the individual by-product (pulp) components in Belgium (the Netherlands). The

fitted values from these regressions are then used as price instruments in the next upper level (level B). Thirdly, we use the slope coefficients, β, as a "correction factor" in deriving the quantities for the individual oilcake and by-product components used in Belgium (which, obviously, partly reflect the EUROSTAT pattern). For example, for soymeal we get

$$\hat{x}_{SOY} = \frac{\partial \hat{p}^{B}_{CAK}}{\partial w_{SOY}} X^{B}_{CAK} = \beta \frac{\partial \hat{p}^{NL}_{CAK}}{\partial w_{SOY}} X^{B}_{CAK} \qquad \text{(A4.3)}$$

where X^{B}_{CAK} is the observed quantity index for oilcakes in Belgium (available from BEMEFA).

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