What are the long-term drivers of food prices? Investigating improvements in the accuracy of prediction intervals for the forecast of food prices

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Abstract

Over the last few years, the prices of the main agricultural raw materials have been highly volatile. The situation is unprecedented, both in the magnitude of the upward and downward volatility observed, and in the number of agricultural commodities affected. Various factors are contributing to these contrasting shifts: the role of emerging countries, changing dietary habits, an increase in energy demand related to the boom in biofuels, adverse weather conditions and speculation. In this paper we try to capture long-term relationships between crop prices and crude oil price using a partial equilibrium and times series method. The study finds little empirical evidence that the crude oil price have a significant influence on the variation of major vegetable crops prices.

JEL Classification:Q11, Q13,Q42

Keywords Partial equilibrium modeling, Forecasting cointegration

1. Introduction

Over the last few years, the prices of the main agricultural raw materials have been highly volatile. The situation is unprecedented, both in the magnitude of the upward and downward volatility observed, and in the number of agricultural commodities affected. Various factors are contributing to these contrasting shifts: the demographic and economic growth of emerging countries, changing dietary habits, an increase in energy demand related to the boom in biofuels, changes in crude oil price, adverse weather conditions and speculation.

The stability of agricultural prices, and beyond that, the stability of foodstuffs, is crucial, as these are staple essentials. In this context of instability, two questions are raised: firstly, what is the respective weight of each of the different factors affecting prices and secondly, what proportion of the price change is structural in nature and how much is cyclical. How are the prices of the main agricultural raw materials formed in the long term?

The use of partial equilibrium models can provide a first medium-term answer to these questions. Usually, this type of model is based on block-by-block specification, a type of construction justified by the fact that the model is primarily intended to be used for medium term projection purposes on , requiring the results simulated by the model to fit the data to a certain extent, and stable relationships. Although one might well question the abilities of models traditionally used in agricultural economics to build medium-term price forecasts. This structural method has been critized as inappropriate in the context of high volatility observed that is observed in some commodity markets..

A second, short-term answer can be provided by the use times series analysis. One might argue that we should use the model that is most consistent with the data based on the results from structural vector autoregressions. For instance, a Vector Error Correction Model (VECM) could lead to a better understanding of the nature of any nonstationarity among the different component series and can also improve longer term forecasting over an unconstrained model.

In this study we investigate the relative performance of both methods to have a better understanding of the dynamics between vegetable and crude oil prices. To achieve these objectives, in a first step we have chosen to build a partial equilibrium, multi-market econometric model (the WEMAC model). That tool can be used for the production of short/medium-term projections (over ten years at most) for a given country or geographical area, or for a world market. Partial equilibrium modelling enables us to incorporate the structural changes that have occurred on world cereal and oilseed markets in recent years. The econometric nature of the modelling and especially its "reproduction of past behaviour" feature gives these projections empirical validity. The approach with the WEMAC model does not describe the price dynamics between the short-term and long-term effects in full. Crucially, that partial equilibrium models do not incorporate the stochastically time-varying volatility that is observed in some commodity markets.

Our proposal therefore, is to test and model in a second step, using time-series mechanisms the characteristics of the price movements, by taking the example of the long-term relationships between crop prices and the crude oil price.

The remainder of the paper is structured as follows. The second section introduces analyzes the main features of the partial equilibrium model and briefly presents the projection results. The third section examines the long run interdependence between major crop prices and examine the dynamic relationship between vegetable and crude oil prices The final section concludes with a discussion of future extensions to this work.

2. Forecasting with an econometric partial equilibrium:The modeling structure

This section outlines the general structure and modelling approach used in the empirical analysis. Before presenting the behavioral equations of each regional sub-models, we first describe the general features of the model, the current country and commodity coverage.

2.1 Characteristics of the WEMAC model

The WEMAC model, or World Econometric Modelling of Arable Crops, is an econometric, partial equilibrium, multi-market model focusing on world cereal and oilseed markets[1].. This model has a double purpose: forecasting and simulation. The WEMAC model is a forecasting tool which generates

1 This was commissioned jointly by the French Ministry of Agriculture and Pluriagri (a partnership created by French producers of arable crops and the Crédit Agricole bank), and is being run by INRA, Rennes (France). Furthermore, it has been financially supported by the “World Econometric or Arable crops”project funded by the European project (Specific Targeted Research project) n°006611.

medium-term annual projections for world cereal and oilseed markets, assuming that agricultural policies remain unchanged. It can also be used to assess the respective roles of traditional operators and emerging countries on world agricultural markets. The WEMAC model is also a simulation tool that can be used to simulate the effects of alternative policy scenarios on cereal and oilseed markets. These scenarios include alternative agricultural, domestic and trade policies, changes in agriculture and external conditions such macroeconomic shocks. The results of the simulation indicate the impact of these alternative scenarios on the equilibrium of world cereal and oilseed markets.

The model is characterized by a number of key features with respect to existing models, which should be highlighted from the start. First, the behavioral equations are estimated on the basis of historical data, rather than being calibrated. One key specificity is the econometric estimation of behavioural equations. One of the shortcomings linked to reference partial equilibrium models when forecasting changes in agricultural commodity markets is undoubtedly the "degree of subjectivity" involved in the adoption of behavioural equation parameters. These models are often called "empirical" models, meaning that the parameters either come from a review of available literature or are calibrated on what experts have said (van Tongeren and van Meijl, 2001). Secondly, as one aim of the WEMAC model is to provide quantitative evaluations of policy reforms, special attention is paid to modeling domestic and trade policy tools for the main producing countries, separating the effect of prices and that of other policy instruments. One of the major characteristics of current WEMAC modelling is that rather than being limited to an aggregate representation of the European Union as a whole, it actually provides information on each major European country, providing country-level estimates for France, Germany, Italy, Spain and the United-Kingdom.

In WEMAC version 2.0, the following countries and geographical areas are modelled: Argentina, Australia, Brazil, Canada, China, India, the European Union (27 Member States [2]), a ‘North Africa and Middle East’ block, Russia, the United States, Ukraine. Countries which are not explicitly modeled are included in an endogenous aggregated block, ‘Rest of the world. The model is based on econometric estimates of behavioral equations. Most of the equations in the model are estimated using annual data

[2] the representation of this latter area is based on the econometric modelling of Germany, Spain, France, Italy, the United Kingdom and an area consisting of the rest of the EU

from the period 1970-2005. The data comes from the USDA's PS&D database and EUROSTAT for the European Union. The commodity coverage include the following grains: soft wheat, durum wheat, barley, corn, rye, oats, soybean, rapeseed, sunflower seed, and for the co-products resulting from the processing of oilseeds, namely oils and meals.

2.2. Specification details of the WEMAC model

The structure of the WEMAC model and its characteristics are given in detail in table 1 to 3. The whole model consists of a set of country or regional sub-models with linkages established across countries and commodities. The structure of each regional sub-model consists of the following behavioral equations: production (harvested area, yield), demand (food use, feed use, stocks), price linkages (prices transmission mechanism between domestic and world prices), trade flows (import and export equations). The behavioral equations are completed by a set of accounting identities to represent market balances. At the world level and for each commodity, a balanced situation between global imports and global exports is imposed; this constraint allows us to specify the world price.

(Insert Table 1 to Table 2)

Domestic supply (equations 1 to 3)

Grains and oilseeds supply

Production in each country is determined as the product of estimated harvested area and yield equations. In each country, we assume a specific separability structure in crop production to explain the production of oilseeds and cereals.

The crop acreage depends on the prices of the different competing crops, the total acreage allocated to field crops and exogenous variables which could have an impact (these variables depend on the country and include such things as domestic policy variables). By and large, the traditional factors behind yield changes are weather conditions, technological innovation (generally introduced as a linear trend with a positive effect), and commodity price. Dummy variables[3] measure gain or loss of yield for a specific crop in specific years, owing in particular to exceptional weather conditions. They are used for years when there are peaks and troughs in yield indicating climate events. The area and

3 A dummy variable attributes a value of 1 to a specific year or period, otherwise a value of 0.

yield equations are jointly estimated using the iterative Seemingly Unrelated Regression Method. Production in country/region is determined as the product of estimated harvested area and yield equations (equation (3)).

Co-Products supply (oils and meals)

The supply levels are derived from oilseed crushing by using extraction rates (see equation 15 for the oils supply).

Domestic demand (equations 4 to 12, equations 16 to 21)

There are different categories of demand in the model: non-feed demand for cereals, feed demand for cereals and oilseed meals, crushing demand for oilseeds, food demand for oils and industrial demand. For cereals, feed and non-feed demands are estimated, while industrial demand is treated as exogenous. Two co-products are extracted from oilseed crushing: oil and meal. For any type of seed considered, the proportions (or extraction rate) of oil and meal obtained are virtually constant, but differ from one type of seed to another. For oilseeds, we estimate the demand for oilseed crushing and feed demand for oilseed meal, food demand of oil, while other types of demand are treated as exogenous.

Food demand for cereals

Non-feed demand depends on the market price for the crop and income (equation(4)).

Food demand for oils

We would like to stress the great care that has been taken over the way food demand for oils is represented in the new version of WEMAC. The original feature of the modelling lies in the estimation of non-feed consumption, which encompasses food consumption and losses, and which can thus be assimilated to human food consumption. The main idea is to take into account the substitute /complementary relationships that exist between the different types of oilseed oils, animal fats, other types of vegetable oil and national specificities. Non-feed consumption is estimated via an AIDS[4] specification (see equation 16 to 17).

4 Almost Ideal Demand System. This is a very general (no explicit utility function specification) and easy to estimate (as it is linear) model. It is in keeping with the economic theory restrictions that are needed to ensure consumer utility is maximised.

Feed demand (cereals, meals)

Because feed is an input into the livestock production equation the theoretical specification of feed demand follows the derived demand approach. The demand for feed use is essentially determined by changes in livestock production and changes in the prices of individual feedstuffs. The determination of feed demand rest upon a two stage framework. The first step, the aggregated feed demand functions for cereals and feed demand for meals, are estimated by the Two Stage Least Square method. Both variables depend on the real price of the representative cereals [5], the price of the cereal substitute product and the price of other protein feeds (protein crops, corn gluten feed, fish and meat meals) (see equation 5). In the second step, demand functions for the different cereals and oilseeds meals are expressed in terms of shares with respect to the total amount of the considered feed demand. For the cereals, they depend on the real prices of competing cereals and on the livestock productions (poultry, beef and pork production). The prices are expressed in the local currency, and deflated by the general consumer price index (see equations 6 to 7). All equations are estimated together with constraint of symmetry on prices and adding-up restrictions. In the same way, each share of meals is a function of the real price of the meal, the real prices of the competing meals and the livestock productions.

Crushing demand for oilseeds

Crushing demand is estimated for oilseeds. The main explanatory variables are the real price of the considering seed oil. The estimation method used is the Two Stage Least Square method. The price series used are the world prices of the seed, the oil and the meal, converted into the local currency. The prices are deflated by the general price index (equation (8)).

Industrial use

In the current modelling, this industrial is considered as exogenous (equations 9 and 19).

Stock level

Finally, the last component of domestic demand is related to the stock level. The stock level generally depends on the market price and on the beginning stock (lagged value of the stock variable). This

5 We used the prices of the main commodities consumed in their respective categories

structure is modified to accommodate policy intervention, especially in the EU, United States and China. The intervention system in the EU is modeled in stocks equations with the intervention price of the considered commodity. In the United States, adjustments are included for cereals to account for government loan programs and stockholding policies: Commodity Credit Corporation6 inventory and Farmers-Owned Reserve program[7]. In China, various schemes to promote self-sufficiency in cereals have been implemented over the last two decades. Hence, we take these programs into account in the changes in Chinese stocks.

Price transmission

A single world price is assumed to exist for each of the commodities. For grains and oilseeds, since producer and market domestic prices are different we have two types of transmission price equations to estimate. Except where these are set by government, domestic prices are linked to world prices via linkage equations including exchange rates.

Trade equations

Many barriers to trade remain in place and there has been an expansion in the relative importance of non-tariff barriers to trade e.g. tariff-rate quotas and preferential access agreements. The nature and operation of such measures varies between countries and in itself complicates the modelling of trade flows (Meilke and al, 1996). Imports mainly depend on the real income of the importing zone, on a price-competitiveness indicator (defined by the difference between the domestic and world prices), and on the customs duties applied to the crop. We distinguish imports by the import regime under which they enter. For countries applying tariff quotas, we do not estimate the total amount of imports, but the level of imports from which the tariff quota used has been subtracted. Hence, imports made under the Tariff Rate Quotas (TRQ) system are exogenous and equal to the scheduled TRQ. Exports depend on the foreign demand addressed to a country, on a price-competitiveness indicator, and on the unit amount of subsidies. A time trend is sometimes included in export equations to represent the entry

6 The Commodity Credit Corporation created to stabilize, support and protect farm income and prices through loans, purchases, payments and others operations. It also helped to maintain balanced and adequate supplies of agricultural commodities and helped in their orderly distribution.

7 Farmers-Owned Reserve (FOR) Program designed to provide storage when wheat and feed grains were in abundant supply and to provide a buffer against unusually sharp price movements. The 1996 Act suspended authority for the FOR.

of new competing countries. For the cereals exported as food aid, instead of considering total exports, we estimate total exports as the volume exported minus the level of food aid.

Closure of the model

For each country model, market clearing is obtained by selecting one behavioural variable as a residual variable. This means that one variable is not estimated but calculated as the residual to check the equilibrium on each regional market. The choice of the residual variable depends on policy and market characteristics relevant for the specific commodity. The market clearing condition that determines the world prices is implemented by forcing the sum of net trade across all countries in the model to zero. On the world market clearing is obtained by endogenous world price. Hence, after modelling each country, the net trade positions are summed across all countries. The clearing identity imposed is that the sum of all countries' net trade is equal to zero. This identity determines the world price of the corresponding commodity. We use Newton's method to solve the world price[8].

2.3 The baseline : Outlook for the corn market

The medium-term forecasts are based on the development of a baseline scenario, grounded in assumptions about policies and assumptions about the variables not explained by the model; macroeconomic variables, agricultural policy instruments and other variables such as data about changes in livestock production, changes in the COP area, and changes in industrial demand for cereals and oilseeds.

The baseline scenario provides projections for the main market variables over the period 2007-2017. The assumptions about changes in macroeconomic variables are generally sourced from the FAPRI 2009 Baseline. World economic growth is assumed to increase at an average annual rate of 3.3% over the period 2008-2017, with a moderate rate of 2.1% for developed countries and accelerated growth of 5.8% for emerging and developing countries. A strong slowdown in global growth in 2009 (+0.9%) is assumed. A recession is expected for the United States and the European Union in 2009, with growth picking up again in the following years. GDP growth varies from 1.9 % in the EU to 9.1 % in China. The rate in developed countries peaks at about 2.5%, while Latin American countries, Russia and

8 A main characteristic in the closure rule of the WEMAC model is that we do not make assumptions on a reference country as in some partial equilibrium models.

Ukraine show stronger growth of between 4% and 5%, and China and India are close to 8%. The new EU member states have an average 4% growth rate over the period. The euro-dollar exchange rate (€1=USD…) is assumed to vary between 1.28 and 1.47 over the period 2007-2017.

For agricultural policies, for the European Union, the CAP Health Check measures are applied, i.e. mainly the decoupling of support (the end of coupling, especially for France and Spain, the abolition of monthly increments and the abolition of set-aside). The successive enlargements of the EU are taken into consideration according to the dates on which they came into effect (EU-15 up to 2003, EU-25 between 2004 and 2006 and EU-27 from 2007 onwards). In the case of the United States, the measures of the 2008 Farm Bill are considered up to 2017. These measures include the loan rate, target prices and direct payments. Trade policies (export subsidies, tariff quotas and customs duties, etc.) are considered unchanged as compared with the year 2005-2006.

The results of the baseline show that the world prices of the main cereals and oilseeds would follow the upward trend observed in 2008. These results are mainly sensitive to the assumptions placed on the macroeconomic variables (GDP, exchange rate).

On the corn market, the world corn price is expected to rise between 2006 and 2017, as a result of the strong increase in consumption in relation to production. The world corn price is expected to reach 198.73 US$/t in 2017 (see Benjamin, Houée-Bigot, 2009 for more details).

With respect to the baseline, we implement a simulation based on an increase of the crude oil price. We assume a rise in the price of oil of 1.25% a year from 2009 onwards. We assume a similar rise in the price of inputs to that in the price of oil.

The impacts on world prices are rather weak even on the corn market. The approach with the WEMAC model does not describe the price dynamics between the short-term and long-term effects in full. Crucially, that partial equilibrium models do not incorporate the stochastically time-varying volatility that is observed in some commodity markets. We check if that result was not linked with the fact that a partial equilibrium does not capture the price dynamics between the short-term and long-term effects in full. Hence, a in a next step we study relationships between crude oil prices and crops prices using cointegration analysis. Cointegration has become a widely used method in case of non-stationary time series data while avoiding the problem of spurious regression.

3. Forecasting with a vector error correction model

A vector correction model was employed to study the relationships between crude oil prices and some major crops prices. This methodology accounts for the possibility of non stationnary in prices and cointegration relationship among prices series. Vector error correction models consider both the long run and short run relationships among variables

The interdependences among corn price, soybean price and oil price are modeled with a VECM model. We use monthly data for the period September 1975 – May 2008.

Let $X_t = (p_t^o, p_t^c, p_t^s)'$ be the vector of oil price, corn price and soybean price. All the price series are taken in logarithms. The VECM model can be written as :

$$\Delta X_t = AE_{t-1} + \sum_{i=1}^{p-1} B_i \Delta X_{t-1} + U_t \qquad (1)$$

Where E_{t-1} is an error correction term and U_t is a vectorial white noise process with dimension 3.

Model building

In the first step, ADF tests are performed for each variable separately. The null of one unit root is systematically non rejected by the data at the 5% confidence level. When performing the same test on first differences of the variable, the null of unit root is systematically rejected in favor of stationnarity so that each variable can be assumed to be I(1).

The optimal number of lags determined by the AIC criterion (when allowing for a maximal lag order equals to 18) is equal to 6. Several test for the absence of autocorrelation of the residuals confirm this result so that *p=6* is the order retained for the VAR model.

We then test for cointegration with the Rank test, as suggested by Johansen . Table 3 presents the results.

Table 3 : Rank test results

Number of cointegration relationships	Trace statitic	P. value
0	42.85	0.003
1	13.37	0.312
3	2.10	0.756

The null of no cointegration relationship is clearly rejected by the data while the null of one cointegration relationship is not rejected at the 5% confidence level. The associated cointegration relationship is given by $(-0.426p_t^o + 7.031p_t^c - 8.565p_t^s + 15.731) \sim I(0)$.

Conditionally to the assumption of a single cointegration relationship, we then perform LR tests for exclusion of each variable from this long-run relationship and Table 4 presents the results.

Table 4 : Tests of exclusion

	Test of exclusion of the variable :			
	p_t^o	p_t^c	p_t^s	constant
LR test	0.775	15.811	18.135	5.244
P value	0.379	0.000	0.000	0.022

As can be seen, the null of exclusion is systematically rejected for both the price if corn and the price of soybean. At the opposite, the data at hand do not permit to reject the exclusion of the oil price variable from this long-run relationship.

Re-estimating the cointegration relationship under the assumption that the price of oil can be excluded leads to the following cointegration relationship $(6.507p_t^c - 8.675p_t^s + 17.456) \sim I(0)$.

The VECM model (1) is finally estimated and impulse response function are calculated over a ten year horizon (120 month). Confidence interval are evaluated by using a Monte Carlo integration method (with 5000 replications) and by calculating the 16% and 84% fractiles (which correspond to one standard deviation if we use symmetrical error bands based upon estimates of the variance).

Impulse response s are calculated so as to get a 1% increase of the shocked variable after 120 months. The corresponding multipliers and the associated confidence intervals are presented in Table 5 (confidence intervals are in parentheses).

Table 5 : Long run price-price multipliers

	Shocked variable		
Response of :	p_t^o	p_t^c	p_t^s
p_t^o	1.00 (0.89 ; 1.10)	0.32 (0.13 ; 0.49)	1.36 (0.05 ; 2.59)
p_t^c	0.07 (-0.03 ; 0.16)	1.00 (0.90 ; 1.10)	1.29 (0.44 ; 2.08)
p_t^s	0.01 (-0.07 ; 0.08)	0.80 (0.72 ; 0.88)	1.00 (0.32 ; 1.62)

The multipliers effects presented in Table 6 show that the impact of oil price on corn and soybean prices are rather limited. However, we have to keep in mind that this effect is essentially attributable to the fact that the price of oil is excluded from the long run cointegration relationship (on purely statistical grounds). As our impulses typically concern the long-run, the cointegration relationship plays a major part in the results contained in Table 6.

Secondly, the corn price has significant effects on both oil price and soybean price. The multiplier effects are systematically positive and confidence intervals suggest that the impulses are very precise. Finally, the soybean price impacts seem to be very strong but the associated confidence interval indicate that they are very imprecise. This result is not surprising as we expect that changes in the amounts and prices observed on the market for an oilseed are largely tied to changes on the market for the related meal and oil.

4. Concluding remarks

We have built a multi-country, multi-market model to measure the weight of structural factors in price shifts - the WEMAC model. The WEMAC 2.0 model consists of a set of sub-models corresponding to aggregated geographical areas and individual countries. The model is based on block-by-block specification, a type of construction justified by the fact that the model is primarily intended to be used for projection purposes, requiring the results simulated by the model to fit the data to a certain extent, and stable relationships. The main agricultural commodities are considered in the model, namely the main cereals (wheat, barley, maize, etc.), the main oilseeds (soybean, rapeseed, etc.) and the products derived from the crushing of oilseeds (meals and oils). The WEMAC 2.0 model can be used to produce projections (over ten years at most) for a given country or geographical area, or for a world market. The model is based on econometric estimates of behavioral equations. The econometric nature of the model, and especially its "reproduction of past behaviour" feature, gives these projections empirical validity.

A first result is that the crude oil price variation does not an important long term effect on major crops prices. We check if that result was not linked with the fact that a partial equilibrium does not capture and describe the price dynamics between the short-term and long-term effects in full. Crucially, partial equilibrium model do not incorporate the stochastically time-varying volatility that is widely acknowledged to exist in commodity markets. Using times series methods, we found that the impact of oil price on corn and soybean prices are rather limited. The time series approach does not require the imposition of theory a priori, thereby avoiding potential misspecification. Also, available time series models can very effectively represent time-varying covariability among price series. This approach does not, however, make use of all available information. The study finds little empirical evidence that the crude oil price have a significant influence on the variation of major vegetable crops prices. First results suggest that the attractiveness of employing a simple partial equilibrium model (i.e. one that does not incorporate stochastic volatility) looks not questionable.

This work is going to be developed in two fields. The first improvement is to evaluate the characteristics of the price movements using structural VAR type modelling (SVAR model), to test and model the long-term relationships between market prices and short-period fluctuations therein. This modelling could incorporates- Long-term restrictions (of the Blanchard-Quah type) by which structural shocks that have persistent effects on prices are identified. These restrictions represent the "break-even" relationships between the prices used.

- Short-term restrictions (of the Cholesky type) intended to identify temporary shocks that affect prices. These restrictions are centred on the regularities in the interdependence of short-term movements in prices (one-way transmission of price movements between leader markets and more limited-size markets, etc.)

By analysing the price response functions, it could then be possible to measure the degree of reaction of those prices to particular structural or cyclical shocks.

Furthermore we could try to capture long-term relationships between crop prices and some macroeconomic variables such as GDP growth exchanges rates. Comparing the results of the WEMAC model with those of the SVAR model could provide us with a measure of the uncertainty concerning the WEMAC model simulations.

Lastly, the information generated by the SVAR model could be used to define a set of assumptions for the simulation scenarios implemented in the WEMAC model, in that it helps to put the effects of different economic variables in order of importance.

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Table 1. Structure of the partial equilibrium model built for the grains and oilseeds market

Supply	Demand
(1) Area harvested $ah_{l,c,} = ah_{l,c}(p_{l,c}/v_c, z_{area,c}, \overline{ah}_c) \qquad l = 1,....,n$ with $\sum_{l=1}^{n} ah_{l,c} = \overline{ah}_c$ where l refers to the different crops cultivated in the considered country (n total number of crops). The definition of the crops is specific to each country studied (linked to the land allocation scheme) i refers to cereals i=1,…k, j refers to oilseeds j= 1,…m. $p_{l,c} = (p_{1c},...p_{i,c},..., p_{n,c})$	(4) Food demand for cereals $(dfo/pop)_{i,c} = dfo_{i,c}(p_{i,c}, y_c)$
(2) Yield equation $yd_{l,c} = yd_{l,c}(p_{l,c}/v_c, T)$	(5) Feed aggregated demand for cereals $dfe_{ti,c} = dfe_{ti,c}(p_{i,c}, p_{meaj,c} p_{cf,c}, K_{a,c})$ where *ti* refer to the total of cereals
(3) Supply equation $s_{l,c} = ah_{l,c} * yd_{l,c}$	(6) Share feed demand for cereals $sdf_{i,c} = sdf_{i,c}(p_{I,c}, K_{a,c})$ Where I refers to cereals I=1…k
	(7) Feed demand for cereals $dfe_{i,c} = sdf_{i,c} * dfe_{ti,c}$
	8) Crushing demand for oilseeds $cr_{j,c} = (p_{j,c}, p_{meaj,c}, p_{hj,c})$
	(9) Industrial use $di_{l,c} = \overline{di}_{l,c}$
	(10) Total demand for cereals $d_{i,c} = ((dfo/pop)_{i,c} * pop + dfe_{i,c} + di_{i,c})$
(11) Ending stocks $st_{l,c} = (p_{l,c}, Z_{st,c})$	
Price transmission (between domestic and word prices) (12) $p_{l,c} = p_{l,c}(p_l, e_c, Z_{p,c})$	
Trade (closure of the domestic market in the country c) (13) $(\exp_{l,c} - imp_{l,c}) = s_{l,c} - d_{l,c} + (st_{l,c} - st_{l,c,(-1)})$	
Closure of the world model (solving for the world price p_l) (14) $\sum_c (\exp_{l,c} - imp_{l,c}) = 0$	

where i,j,l: crops; c: country;

Table 2. Structure of the partial equilibrium model built for the oils markets

Supply	Demand
(15) supply equation $s_{hj,c} = t_{hj,c} * cr_{j,c} \quad j = 1,....,m \quad hj = 1,...,M$ $s_{hj,c}$ oil supply linked to the j oilseed $t_{hj,c}$ oil extraction rate	(16) expenditure share of food oil demand $w_{hj,c} = \alpha_{hj} + \sum_{hj=1}^{M} \gamma_{hj,k} Ln(P_{hj}) + \beta_{hj} Ln\left(\frac{E_c}{IP_c}\right)$ with $Ln(IP_c) = \sum_{hj} w_{hj} * Ln(P_{hj,})$
	(17) Food oil demand $dfo_{hj,c} = (w_{hj,c} * E_c) / p_{hj,}$
	(18) Feed oil demand $dfe_{hj,c} = \overline{dfe}_{hj,c}$
	(19) Industrial use $di_{hj,c} = \overline{di}_{hj,c}$
	(20) Total demand $d_{hj,c} = (dfo_{hj,c} + dfe_{hj,c} + di_{hj,c})$
	(21) Ending Stocks $st_{hj,c} = (p_{hj,c}, Z_{st,c})$
No Price transmission equations (world prices in behavior equations)	
Trade (closure of the domestic market in the country c) (22) $(\exp_{hj,c} - imp_{hj,c}) = s_{hj,c} - d_{hj,c} + (st_{hj,c} - st_{hj,c,(-1)})$	
Closure of the world model (solving for the world price p_{hj}) (23) $\sum_{c} (\exp_{hj,c} - imp_{hj,c}) = 0$	

where hj: oils linked to the j oilseed; c: country