Making the world market price endogenous within the AGMEMOD modelling framework: an econometric solution

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Abstract

This paper aims at making the world price endogenous within the AGMEMOD modelling approach. This approach constructs country-level commodity market models where supply and demand sides are equalized on the basis of the observed domestic prices. These prices are endogenous as they depend (price transmission equation) on a EU key-price, which is, in turn, endogenously determined by the world price (price formation equation). The world prices, however, are assumed to be exogenous. To make the world price endogenous, we propose a system of equations where the EU key-price and the world price are simultaneously determined. This system of equations, written in a dynamic and error-correction form (VECM), substitutes the usual price-formation equation, while price transmission across EU countries remains unaffected. This approach is here applied to the case of soft wheat and results compared to those obtained by using the conventional AGMEMOD approach.

Keywords: Price Formation and Transmission, Commodity Market Models, VECM
EconLit Classification: Q110, Q170

1. Introduction

This paper explores international agricultural price transmission with specific reference to soft wheat. In particular, by the use of econometric approaches recently proposed in this literature, the paper aims at making the world price endogenous within the AGMEMOD modelling framework. This framework constructs country-level commodity market models as dynamic partial equilibrium models[1] where supply and demand sides are equalized on the basis of the observed domestic prices. These prices are endogenous as they depend, through a price transmission equation, on a EU key-price which is in turn endogenously determined by the world price through a price formation equation. The world price, however, is assumed to be exogenous.

To make the world price endogenous, we propose a system of equations where the EU key-price and the world price are simultaneously and reciprocally determined. This system of equations, written in a dynamic and error-correction form (a VECM), can then be rewritten in reduced form such that both prices only depend on lagged values. The recursive structure of the model is thus maintained and, in this form, these price equations can be included in the whole combined model in place of the usual price-formation equation to generate projections upon specification of appropriate scenarios. Price transmission across EU countries and commodities remains unaffected. This approach is here applied to the soft wheat market and results are compared to those obtained using the conventional AGMEMOD approach to price formation. A further implication of this modelling approach is that it can better take into account the role of policy instruments in price formation. In particular, the reciprocal relation existing between the EU key-price and the world price depends on whether the world price is higher or lower than the intervention price. The latter is deemed to be a sort of threshold, under which the world price doesn't affect the European one anymore. Consequently, the proposed approach allows the AGMEMOD model to selectively link the EU key-price to the world price or to the policy instrument depending on which of them is actually higher, but still letting the world price be itself affected. Therefore, a further insight on how policy instruments may affect price formation is provided and a more in-depth policy analysis upon plausible policy scenarios is achieved.

The structure of the paper is the following. In section 2 evidence and approaches concerning international agricultural price transmission are shortly reviewed. Section 3 presents the general characteristics of the AGMEMOD modelling framework and the specific role of price formation and transmission thereof. Section 4 describes the method here proposed to make the world price endogenous and, in addition, to take into consideration the role price policy plays in affecting international price transmission. The application of this approach to the current "AGMEMOD EU15 combined model", and to the specific case of soft wheat price, is presented in section 5. Section 6 concludes.

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[1] See van Tongeren et al. (2001) for an extensive survey on agricultural markets' models.

2. Agricultural price transmission in empirical literature: a short review

Price transmission in agricultural commodities markets is an issue which has received considerable attention (Fackler and Goodwin, 2001). Unfortunately, analyses often rely on commodity prices only, which has implied the use of increasingly sophisticated econometric techniques and the lack of appropriate concern for policy factors. Some modelling approaches, on the other side, while making explicit use of policy variables in price transmission equations, still rely on some simplistic assumptions, like the "small country hypothesis" for the EU in the AGMEMOD model: the EU is assumed not to have an influence on world prices, which enter the model exogenously.

Considering the time series properties of the data could represent a first step forward. Referring to the general framework of the Law of One Price[2] (LOP), if two non-stationary price series are found to be cointegrated, then the cointegration vector can be interpreted as the long-run relation existing between them (the LOP itself), while short run dynamics will account for short-run deviations from it. The coefficients of the cointegration vector can be read as price transmission elasticities. They are a measure of the co-movement of prices, and show to which extent changes in world prices are transmitted back to within-countries (Thompson and Bohl, 1999). A number of factors are expected to have an effect on them (Conforti, 2004), namely domestic and border policies. Despite the fact that the use of cointegration techniques suffers from some drawbacks (Fackler and Goodwin, 2001; Miljikovic, 2003), they have been applied in quite a lot of empirical works (Fackler and Goodwin, 2001), and are here of particular interest as they allow going beyond the assumption of exogeneity of world prices.

In particular, here the analysis focuses on soft wheat, a commodity whose market has been deeply influenced by the CAP. Policy regimes play a significant role in soft wheat production and export shares (Barassi and Ghoshray, 2007); the CAP is a case in point, since during the 1980s the EU emerged as one of the largest exporters of wheat, having previously been a net importer (Ghoshray et al., 2000). Since the 1990s, the EU Common Agricultural Policy (CAP) has considerably evolved towards more market oriented mechanisms but, despite the fact that intervention prices were considerably reduced, thus narrowing the distance from world prices, market access has not been improved to the same extent (Anania, 2007). In Listorti (2007), evidence of cointegration has been found between the EU domestic price and the "EU external reference price", constituted by the maximum between the intervention price and the US price for a competing destination on world markets. This means that the presence of an internal regulatory framework for EU soft wheat actually played a strong role, especially until 1993. After this date, the reduction of the intervention price and the developments in international markets caused US prices to be much more often above the intervention price, thus influencing the EU internal price despite the fact that the same border protection mechanism had, meanwhile, kept being in place.

All this evidence and consequent considerations, either concerning econometric issues or policy insights, are often disregarded in large multi-commodity partial equilibrium models. Even though they are of major interest for agricultural and trade policy analysis (van Tongeren et al., 2001; OECD- FAO, 2007), their intrinsic complexity often prevents from a more careful consideration of how price formation and transmission, and the consequent policy instruments, are modelled and, above all, of how prices may be mutually dependent. With reference to the AGMEMOD modelling, here we aim at making a step forward in this direction.

3. The AGMEMOD modelling approach

3.1. Commodity market models

According to the general AGMEMOD modelling strategy, the EU aggregate model is built by combining the EU country models, which are, in turn, obtained by merging single commodity sub-models.

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[2] Markets linked by trade and perfect arbitrage (and competition) will have a unique price, when expressed in the same currency, net of transportation costs.

Rest of the world variables (namely, world market prices), macroeconomic variables (e.g., inflation rate and *per capita* GDP growth), and policy variables (e.g., intervention prices) enter the model exogenously (AGMEMOD Partnership, 2007a; Chantreuil et al., 2005; Esposti and Lobianco, 2005). Commodity models across countries are based on a common template and are estimated on historical data using the same variable definitions and data sources. A set of common exogenous variables (including macrovariables, policy measures and key-prices) enters any commodity market. Once the model equations have been estimated, all country commodity markets can be solved in any country, that is, for any commodity the "supply and use" identity is imposed by computing the closing variable (imports or exports). Finally, all solved country models can be combined into one aggregate EU model, which is in turn solved by imposing in any market the supply and use identity through the EU closing variable (EU net exports) (AGMEMOD Partnership, 2007a; Chantreuil et al., 2005).

A commodity country model is linked to the other countries through a price transmission relationship, where an EU key-price drives price formation in any domestic market. The EU key-price is usually set as the price observed in the most important national market for that commodity. Therefore, for any commodity, a key-market is identified. Moreover, commodity models may be linked among themselves on either the supply or the demand side, according to land allocation decisions, technical interdependencies, consumption complementarity/substitutability relations (Esposti and Lobianco, 2005). Figure 1 depicts this general modelling structure and, in particular, shows how prices are formed and transmitted. In fact, commodity market models are dynamic for the presence of lagged variables among drivers. Therefore, any country model, as well as the combined EU model, can generate projections of the endogenous variables, by feeding the model with projections of the exogenous variables, using the estimated parameters and imposing market closure. These projections are generated by solving the estimated model in a recursive way over the projection period; that is, the equilibrium in a period is the starting point to solve the next equilibrium. Since policy (CAP) measures belong to the vector of exogenous variables, model projections are generated over a set of alternative values of these measures, or, in other words, over a set of alternative policy scenarios.
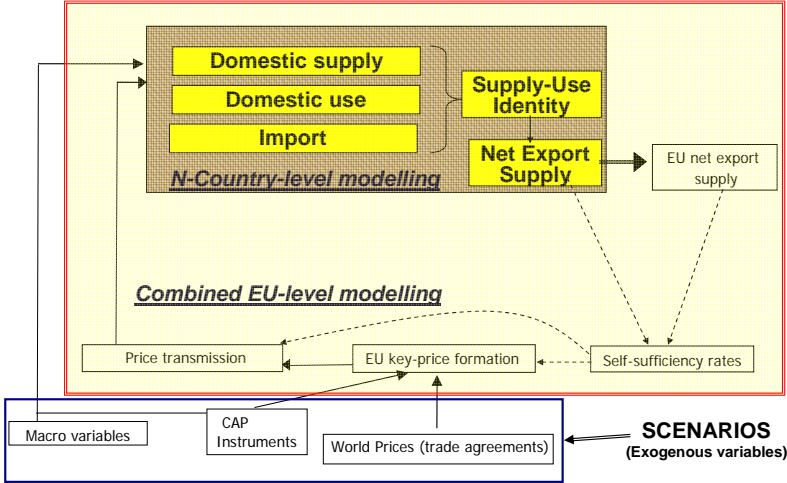

Figure 1. Country model general structure and price formation/transmission within AGMEMOD. Source: AGMEMOD2020 Project.

Consequently, any commodity model is formed by a set of either behavioural equations or identities. Behavioural equations allow estimating and projecting the key endogenous variables in their respective market; identities impose the market closure conditions (AGMEMOD Partnership, 2007a; Chantreuil et al., 2005; Esposti and Lobianco, 2005)[3]. These equations can be grouped into three sets: supply side, demand side, price and stocks formation. A market closure equation (identity) completes the model. As both demand and supply side equations are driven by the commodity market price, a critical aspect in building these

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[3] An exhaustive presentation of the complete econometric model with the explicit functional specifications of estimated equations can be found in Esposti and Lobianco (2004).

commodity models concerns the specification and estimation of equations describing how market price is formed.

3.2. Price formation and transmission within AGMEMOD modelling

Within the AGMEMOD modelling approach, market price is endogenously determined (AGMEMOD Partnership, 2007a; Chantreuil et al., 2005; Esposti and Lobianco, 2005). It simply means that any commodity model includes one equation where the price is the dependent variable and the independent variables explain how that price is formed within that market. In fact, commodity prices are generated in a two-step process. Firstly, a country is identified as the most important EU market (France for soft wheat) and in this country the commodity model includes a *price formation equation*. This equation aims at capturing all exogenous variables affecting price formation within the EU and, in particular, the world market price, price policies (intervention prices, for instance), trade agreements, etc.. In addition, key-price formation may include as a determinant the lagged EU self-sufficiency rate, thus making the key-price recursively respond to the previous year's outcome. Secondly, the key-price is transmitted into any other domestic market, through a *price transmission (or price linkage) equation* that makes the domestic price be driven by the EU key-price and other possible explanatory variables, e.g., the own country self-sufficiency rate (or net exports) for that commodity.

More formally, the general (implicit) form of these two equations can be described as follows. Consider the i-th commodity and the c-th country over the whole sets of N and M modelled commodities and countries, respectively. The price formation equation can be written as:

(1a) $\qquad P_{i,k,t} = f\left(P_{i,w,t}, P_{i,\mathrm{int},t}, v_{i,t}\right)$

where $P_{i,k,t}$ is the i-th commodity key-price within the EU at time t, $k \in M$ being the key-market (i.e., key-country), $P_{i,w,t}$ and $P_{i,\mathrm{int},t}$ the world and intervention prices, respectively, and $v_{i,t}$ a vector of additional variables which could affect the key-price formation. In particular, we might include the lagged key-price (i.e., at time t-1), the lagged EU self-sufficiency rate or net exports of the i-th commodity, other possible policy measures that, in combination with the intervention price, may segregate the EU market from the world market (e.g., import tariffs, export subsidies). Details on this equation for soft wheat are reported in Annex 2.

The price transmission (or price linkage) equation can be written as:

(2) $\qquad P_{i,c,t} = f(P_{i,k,t}, v_{i,c,t}, v_{i,k,t})$

where $P_{i,c,t}$ is the i-th commodity price in c-th country at time t, where $c \in M$, $c \neq k$; $v_{i,c,t}$ and $v_{i,k,t}$ are two vectors of c-th and k-th country-specific variables, respectively, which could have an impact on price transmission from the k-th to the c-th country; namely, the respective self-sufficiency rates or net exports. In equations (1a) and (2), all prices are implicitly expressed in the same currency, that is, Euros (€). World prices, however, are expressed in US dollars ($) in most statistical sources. Thus, even when they remain constant, world prices may vary, when expressed in €, just due to a variation of the €/$ exchange rate ($EXC_{\text{€}/\$}$). Therefore, we can make the role of the exchange rate explicit by just rewriting equation (1a) as follows:

(1b) $\qquad P_{i,k,t} = f\left(EXC_{\text{€}/\$,t} \cdot \overline{P}_{i,w,t}, P_{i,\mathrm{int},t}, v_{i,t}\right)$

where $\overline{P}_{i,w,t}$ indicates the world price expressed in $.

It must be noticed that the two-step endogenous determination of market prices within the AGMEMOD model does not imply that they are market-clearing prices. In other words, these prices are not computed, given internal supply and demand, to make markets close. As mentioned, market closure is achieved, at either the country or the EU level, by just imposing the supply-use identity, given the market price, that is, by computing one market-closing variable (imports or exports at the country level; net exports at the EU level). Moreover, these prices are driven by variables assumed to be exogenous, particularly world market prices, that could actually be themselves dependent on the EU price. By assuming exogenous world prices, we implicitly assume that the EU always behaves as an irrelevant country in the world market, while it is indeed a major net exporter for several main commodities, including soft wheat. This seems to be a major

limit of the AGMEMOD modelling approach, and possible solutions may be proposed and adopted to deal with this drawback.

4. Endogenizing the world market price

4.1. The dynamic simultaneous equations (VECM)

To make the world price endogenous within the AGMEMOD approach, there are two major possible alternatives. The first is to make the world price be computed as the market clearing (or closing or solving) price. This is the solution adopted in the FAPRI modelling approach (FAPRI, 2003a; 2007) but might be problematic within AGMEMOD. Firstly, because prices are not computed in this way for the EU market; secondly, because it can be computationally difficult to achieve this model closure; lastly, because it can generate, at least for some years, unreliable or unrealistic results or, in any case, much more volatile prices in projection periods than what observed in historical (real) data.

The second solution aims at endogenizing the world price in an econometric sense without any model closure at the world market level. It simply consists of substituting the key-price formation equation, that is, equation (1b), with a system of two simultaneous equations where both the EU key-price and the world price are endogenously determined and are mutually dependent, to represent the fact that if the world price affects the EU key-price, the other way round might be also true, that is, the EU key-price influences the world price. This system of equations should be specified and estimated in a dynamic form, that is, with lagged values among the regressors, and this not only because this specification might better detect the underlying data generation process, where adjustments and persistency may occur, thus making short-run and long-term relations among prices continuously mixed-up. The major reason for a dynamic specification is that it better fits the primary character of the AGMEMOD modelling approach, namely to generate projections of endogenous variables, given a set of projections of exogenous variables (that is, scenarios), thanks to its dynamic (or recursive) structure. In fact, by writing this system of equations in a reduced-form specification, we can compute the current values of both prices as a function of their lagged values and, possibly, of current values of exogenous variables. Therefore, in this form, both the EU key-price and the world price can be endogenously projected.

A dynamic system of simultaneous equations in reduced form is typically depicted as a VAR model. Consequently, here we specify a VAR model with two endogenous variables (the prices) and the respective appropriate lags. More precisely, as the price series were found to be I(1) and cointegrated, the model is specified as a VECM (Vector Error Correction Model).

4.2. The new price formation and transmission equations

The specification and estimation of the VECM model here adopted concern soft wheat market (and prices) and are clarified and detailed in Listorti (2007). Here, we just want to outline the major aspects of this model with respect to the functioning of the AGMEMOD modelling framework. The role of the intervention price cannot be disregarded. This policy instrument (together with other trade policy measures, such as tariffs and export subsidies or taxes) mainly aims at partially or totally segregating the EU internal market from the world market. We might argue that when the world price falls below the intervention price, its transmission to the EU price is quite limited, if any, and the *vice versa* also holds true: the EU internal price follows the world price only when above the intervention price. The intervention price empirically turns out to act as a threshold below which the world price has no effect on the EU internal price. In Listorti (2007), in fact, cointegration is observed between the EU soft wheat price and a combination of soft wheat world and intervention prices.

Firstly, the VECM is estimated using monthly price data and not annual data. This is done mainly because annual data would allow estimation over a very short observation period (about 25 years, just 25 observations), while monthly data permit estimation on a much larger sample (from 1978:12 to 2003:12, 301 observations), thus achieving a much better goodness of fit and statistical quality of the estimation

results. Moreover, monthly data can really better capture the underlying relations existing among prices, and in particular those short-run adjustments often linked to seasonality or short cycles. Thus, higher frequency data can actually better detect the longer-term linkages between the two prices as they can better separate them from these shorter-terms effects. Secondly, our VECM model uses the logarithms of prices. The model is specified in a log-linear form. Therefore, to integrate these equations in the AGMEMOD model, modelled prices must be eventually rewritten in levels.

The monthly-data VECM model estimated in Listorti (2007), and adopted here, is the following[4]:

$$(3) \qquad \Delta \mathbf{p}_s = \boldsymbol{\alpha} \mathbf{z}_{s-1} + \boldsymbol{\Gamma}_1 \Delta \mathbf{p}_{s-1} + \boldsymbol{\Gamma}_2 \Delta \mathbf{p}_{s-12} + \mathbf{u}_s$$

where $p_s = \ln P_s$, $\mathbf{p}'_s = \begin{pmatrix} p_{k,s} & p_{w,s} \end{pmatrix}$ is the vector of prices observed in s-th month, with s = 1,…,S and S=301, and $p_{w,s} = \max\left(p_{US,s}, p_{\text{int},s}\right)$. $\mathbf{z}_{s-1} = \beta_0 + \beta_1 p_{k,s-1} + \beta_2 p_{w,s-1}$ is the cointegration vector, expressing the long-term relation between prices, $\boldsymbol{\alpha}$ is the (2x1) matrix of adjustment coefficients, $\boldsymbol{\Gamma}_1$ and $\boldsymbol{\Gamma}_2$ are (2x2) matrices of coefficients expressing short-run relations. Finally, $\mathbf{u}_s$ is the usual vector of i.i.d $(\mathbf{0}, \boldsymbol{\Omega})$ disturbances. To convert this model from monthly to annual observations, we can just take the average of the lhs and rhs of equation (3) over 12 months (that is, $\Delta \mathbf{p}_t = \frac{1}{12} \sum_{i=0}^{11} \Delta \mathbf{p}_{s-i}$; we also assume that $\mathbf{z}_{t-1} \cong \frac{1}{12} \sum_{i=0}^{11} \mathbf{z}_{s-i-1}$). Moreover, we might think that the shorter-term adjustments, namely the one-month lagged terms $\Delta \mathbf{p}_{s-1}$, are expected to be negligible over annual observations. Once these necessary simplifications have been made, the VECM can be rewritten as follows:

$$(4a) \qquad \Delta \mathbf{p}_t = \boldsymbol{\alpha} \mathbf{z}_{t-1} + \overline{\boldsymbol{\Gamma}}_2 \Delta \mathbf{p}_{t-1} + \overline{\mathbf{u}}_t$$

where $\overline{\boldsymbol{\Gamma}}_2 = \frac{\boldsymbol{\Gamma}_2}{12}$ and $\mathbf{u}_t = \frac{1}{12} \sum_{i=0}^{11} \mathbf{u}_{s-i}$. To express equation (4a) in levels, instead of first differences, we can rewrite it as:

$$(4b) \qquad \mathbf{p}_t = \mathbf{p}_{t-1} + \boldsymbol{\alpha} \mathbf{z}_{t-1} + \overline{\boldsymbol{\Gamma}}_2 \Delta \mathbf{p}_{t-1} + \overline{\mathbf{u}}_t$$

Including this dynamic simultaneous price formation within the AGMEMOD approach eventually means substituting (1b) with the following system of equations:

$$(5a) \qquad \begin{cases} p_{k,t} = \alpha_1 \beta_0 + (1 + \alpha_1 \beta_1) p_{k,t-1} + \alpha_1 \beta_2 p_{w,t-1} + \frac{1}{12}(\Gamma_{11} \Delta p_{k,t-1} + \Gamma_{12} \Delta p_{w,t-1}) + \overline{u}_{1t} \\ p_{w,t} = \alpha_2 \beta_0 + \alpha_2 \beta_1 p_{k,t-1} + (1 + \alpha_2 \beta_2) p_{w,t-1} + \frac{1}{12}(\Gamma_{21} \Delta p_{k,t-1} + \Gamma_{22} \Delta p_{w,t-1}) + \overline{u}_{2t} \end{cases}$$

Generating price projections within equations is relatively straightforward. Starting from the last observable year, t = 0, we firstly compute $p_{w,0} = \max\left(EXC_{€/\$,0} \cdot \overline{p}_{US,0}, p_{\text{int},0}\right)$, and then we can iteratively generate price projections over the whole projection period. Since we assume that the intervention price acts as a threshold above which the US (=world) price is active, at any iteration t $p_{w,t}$ is compared with $p_{\text{int},t}$ and, if below it, the latter is taken as the "true value" of the world price for the following year. In other words, the maximum value resulting from this comparison is then assumed to be $p_{w,t}$, and the iteration can proceed. As in (5a) variables are expressed in logarithms, at any iteration we can compute the correspondent price levels simply as $P_{k,t} = e^{p_{k,t}}$ and $P_{w,t} = e^{p_{w,t}}$.

Finally, in any country model, with the exception of the key-market, the key-price is transmitted to the domestic price according to price transmission equation (2). The empirical specification of (2) is the following[5]:

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[4] As the model is here applied to the soft wheat case, the notation skips the commodity index i=1,…,N. More details on this VECM estimation are reported in the Annex.

[5] According to the current AGMEMOD model, the estimated coefficients for the Italian soft wheat price are: $\gamma_0 = -7226.83$; $\gamma_1 = 2.43$; $\gamma_2 = 0.00$; $\gamma_3 = 3142.41$.

(6) $P_{i,c,t} = \gamma_0 + \gamma_1 P_{i,k,t} + \gamma_2 SSR_{i,c,t-1} + \gamma_3 SSR_{i,k,t-1}$

where $SSR_{i,c,t}$ and $SSR_{i,k,t}$ indicate the self-sufficiency rate for the i-th commodity at time t-1 in the c-th and k-th country, respectively, and $\gamma' = \begin{pmatrix} \gamma_0 & \gamma_1 & \gamma_2 & \gamma_3 \end{pmatrix}$ is a vector of estimated parameters where, in particular, price transmission elasticity at time t can be easily calculated as $\varepsilon_{c,t}^{k} = \gamma_1 \dfrac{P_{i,k,t}}{P_{i,c,t}}$.

5. The empirical exercise

5.1. Soft wheat market projections to 2020

The price formation modelling approach described above is here applied to the soft wheat market according to the most recent "AGMEMOD2020 EU15 combined model" (November 2007 version). The respective baseline is also adopted (AGMEMOD Partnership, 2007a; 2007b), although the €/$ exchange rate is here updated and ranges between 0.7 and 0.8 over the whole projection period (2008-2020). Within the AGMEMOD model, cross-commodity and cross-country linkages are so relevant that changing price formation on several markets would make the interpretation of results particularly complex. Therefore, we focus on one market only, leaving all other commodity models unaffected.

The soft wheat EU key-price is the French price, then transmitted to all other national markets. Key-price formation is specified in the two abovementioned forms: the conventional AGMEMOD approach, the key price being driven by two exogenous prices (the US price, acting as world price, and the intervention price) and other policy and model variables (see Annex 2); the alternative approach here proposed, where the key-price and the US price are simultaneously (i.e., endogenously) generated. For simplicity, we refer to these alternatives as the *exogenous* and the *endogenous* price formation, respectively. The specification of the price transmission equation across EU countries, as well as all other model equations, remains the same in both approaches. Nonetheless, as a consequence of the different French price formation (*direct effects*), different national prices may still be observed between the two approaches and the same holds true for all other model equations directly or indirectly depending on soft wheat price (*indirect effects*).

Besides generating projections under the current AGMEMOD *baseline scenario* (with updated €/$ exchange rate), we also report results according to one alternative scenario generated by merely imposing in 2008 a +20% shock on the €/$ exchange rate then maintained afterwards. Consequently, under this *shock scenario*, the €/$ exchange rate ranges between 0.85 and 0.95. By moving towards parity, we thus implicitly impose an increase of the soft wheat US price, when expressed in €. Projections reported and discussed below are therefore generated by running the current "AGMEMOD2020 EU15 combined model" under four specifications: the two versions (*exogenous* and *endogenous*) of the price formation equation and the two scenarios (*baseline* and *shock*), respectively.

5.2. Results
5.2.1. Direct effects

Figures 2 and 3 and Table 1 show the direct effect of alternative formulations of soft wheat French price formation. They report the French (FR) and US prices, together with the intervention price, under the four alternative cases, that is exogenous and endogenous price formation under baseline (Figure 2) and shock scenario (Figure 3). By indexing prices with respect to the US price in 2005, we may better appreciate the different patterns emerging among alternative projections (Table 1).

Of major interest here, is to assess whether the model is more stable and robust under the alternative specification of price formation here proposed, and the respective response to shocks more reliable. More generally, the exercise may also be helpful to understand how the performance of the AGMEMOD model can be improved with specific reference to one of its key drivers, namely key-price formation, by making it

more reliable, realistic and robust with respect to changes in other exogenous drivers (the exchange rate, for instance).

Three key results emerge. Firstly, when endogenously generated, the US price is much smoother and this regularity affects the last in-sample observations already. The explanation of this in-sample behaviour is straightforward. In fact, model projections are generated starting from the last historical observations (that is, from 1996 onwards in the present case) to make them assume consistent values and closer to the real ones. Thus, as exogenous variable, the US price simply takes the historical (observed) values in the 1996-2007 period while, on the contrary, as endogenous variable, it is generated by the model and not affected by exogenous price fluctuations. In the 2008-2020 projection period, however, both exogenously and endogenously generated US prices tend to a more regular pattern showing a significant convergence toward 160€/tonn. Regularity of the endogenously generated US price depends on the fact that it is linked to the French price, in the long run, according to the estimated cointegration relation. As no other exogenous drivers enter in the estimated VECM model, short run variations progressively vanish over the projection period and, once the adjustment process is completed, prices' behaviour is only generated by the long run relations among them. Eventually, both prices not only show regular patterns but also inevitably tend to remain constant over time. This is not unavoidable, however, as it could be prevented by merely introducing exogenous regressors in the VECM specification (for instance, a trend variable or other international prices).

A second important consequence of endogenously modelling the US price is that the two (US and French) prices are now closer. This is not only achieved by means of the cointegration relation, that maintains the two prices closely connected as short-run effects vanish. Actually, another major explanation concerns the role of intervention price. In exogenous price formation, intervention price always enters as a major driver (regressor) of the French price together with US price itself (see Annex 2). In fact, the parameter associated to intervention price is much larger than the US price parameter (0.59 and 0.16, respectively): as clearly emerges from Figures 2 and 3, the consequence is that the French price is much closer to the intervention price and quite far from (and, in particular, lower than) the US price. On the contrary, according to the endogenous price formation, intervention price only plays a role when it is higher than US price: this happened during the 1990-1992 period when, indeed, French price more closely followed intervention price than US price. As soon as the intervention price falls below the US price, endogenous price formation makes it irrelevant with respect to the French price (it is another form of decoupling....), which then starts following the US price more strictly. This seems, in fact, more consistent with historical observations (see Figures 2 and 3) and, above all, with the intervention price itself as a policy measure. As already outlined, the intervention price is here modelled as a sort of a lower threshold for the US price (Listorti, 2007). This threshold is exogenous: as in the "old" exogenous model, the intervention price is still exogenously determined by the European Commission. It happens that, from 1993 onwards, intervention price is always below US price, then making the threshold not active.

A final important difference emerging between the two alternative price formation models concerns response to exchange rate variations. Figure 3 simulates the effect of € depreciation with respect to $. As expected (the US price being expressed in €), the shock determines an increase of the US price in both cases. However, under endogenous price formation, this exchange rate variation considerably affects the French price, as well. In particular, the two prices are linked, in the long-run, through a cointegration relation showing a close-to-1 elasticity, as should be according to the LOP (Listorti, 2007) (see also Annex 1). The exchange rate shock, therefore, is almost entirely transmitted to the French price which now becomes progressively increasing and higher compared to the former €/$ exchange rate. On the contrary, and quite implausibly, exogenous price formation would suggest a permanent shock in the US price nonetheless leaving the French price almost unaffected.
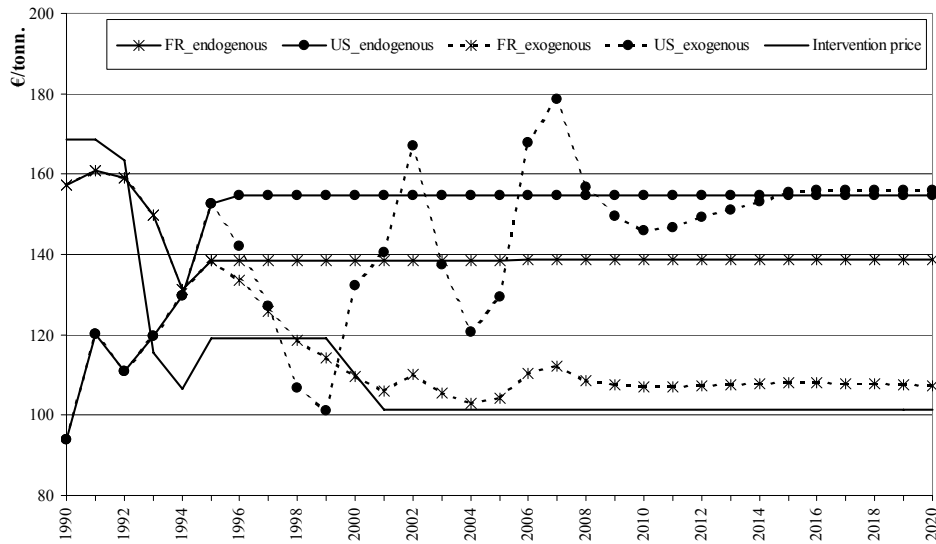
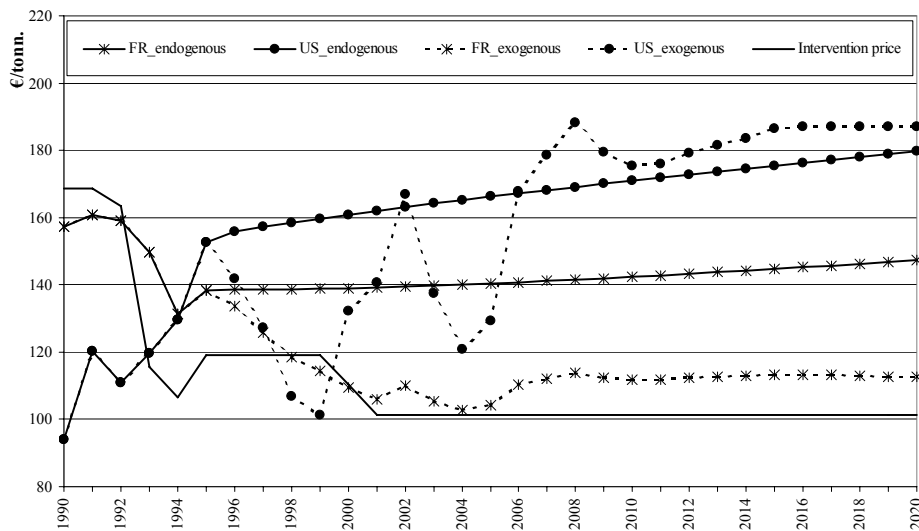Figure 2. French and US price projections according to the two price formation specifications: baseline

Figure 3. French and US price projections according to the two price formation specifications: shocked €/$ exchange rate

5.2.2. Indirect effects

We might report many model variables (yields, land allocation, consumer demand, etc.) whose projections are affected, even slightly, by the change of soft wheat price formation. The indirect effects induced by this alternative modelling of US and French price formation, however, can be appreciated just by looking at price transmission from this EU key-price to another domestic price. In the present case, we consider the Italian soft wheat price. According to equation (6), in fact, the Italian price (IT) is not only driven by the French one, but also by the Italian and French self-sufficiency rates. Besides price transmission elasticity, what matters in price transmission from the EU key-market to any other EU country is the excess of supply (inducing exports) observed in the key-market and the excess of demand (inducing imports) observed in the receiving EU country.

Price transmission from France to Italy is by itself quite elastic (elasticity greater than 1) (see note 5), while the increase of the French self-sufficiency rate, by inducing greater export levels, has a further positive effect on price transmission, as expected. Therefore, as French supply and demand themselves (thus, self-sufficiency) are both affected by the change in domestic price induced by the different price formation, the Italian soft wheat price is affected by this alternative modelling twice. Firstly, because French price changes; secondly, because French self-sufficiency varies: both effects influence price transmission to

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the Italian soft wheat market in the same direction. This indirect and somehow complex mechanism can be appreciated in Figures 4 and 5 and in Table 1.

Table 1. Indexed prices across scenarios and price formation models (2005 US price in € = 100)

	1990	1995	2000	2005	2010	2015	2020
FR_endogenous-baseline	121.6	107.0	107.1	107.1	107.2	107.2	107.2
IT_endogenous-baseline	122.1	137.0	143.1	144.2	143.0	143.5	144.6
US_endogenous-baseline	72.6	118.0	119.6	119.6	119.6	119.6	119.6
FR_exogenous-baseline	121.6	107.0	84.7	80.5	82.8	83.5	83.0
IT_exogenous-baseline	122.1	137.0	84.4	73.8	78.9	81.4	81.1
US_exogenous-baseline	72.6	118.0	102.3	***100.0***	112.9	120.2	120.5
FR_endogenous-shock	121.6	107.0	107.5	108.5	110.1	111.9	113.9
IT_endogenous-shock	122.1	137.0	144.0	147.9	149.8	154.6	160.8
US_endogenous-shock	72.6	118.0	124.4	128.5	132.2	135.6	138.9
FR_exogenous-shock	121.6	107.0	84.7	80.5	86.4	87.5	87.1
IT_exogenous-shock	122.1	137.0	84.4	73.8	87.7	90.8	90.6
US_exogenous-shock	72.6	118.0	102.3	***100.0***	135.5	144.2	144.6
Intervention price	130.3	92.2	85.2	78.3	78.3	78.3	78.3

By comparing endogenous and exogenous price formation, we notice two major aspects. On the one hand, the Italian price is evidently driven by the French price which is, in turn, driven by the US price. Thus, the Italian and the French prices show the same pattern. However, while these two prices are very close in the exogenous price formation case (where the Italian price falls even below the French one) and both close to intervention price, under endogenous price formation the Italian price is clearly above. On the other hand, by comparing the Italian price with the US one (Table 1), it is worth noting that while the former is lower under exogenous price formation, it becomes significantly higher when endogenous formation is admitted. Though the Italian price is not directly driven by the US price, this result by itself makes evident how relevant a change in key-price formation may be within AGMEMOD modelling framework.
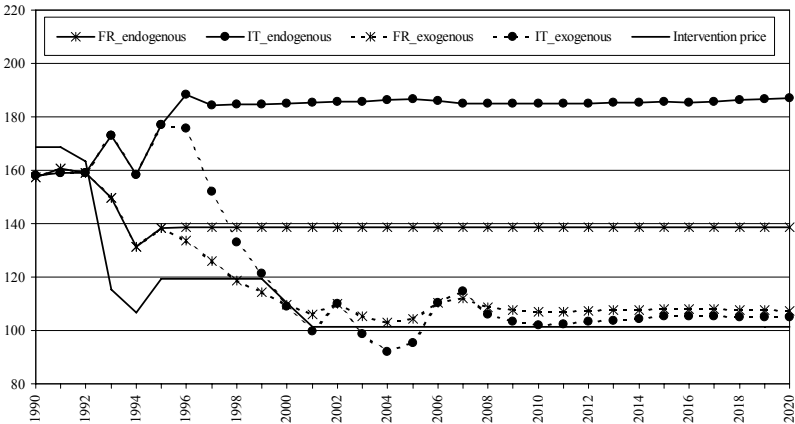

Figure 4. French and Italian price projections according to the two price formation specifications: baseline
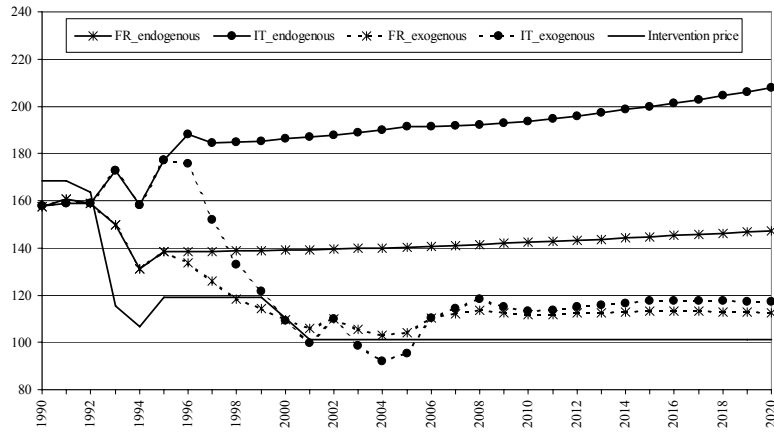
Figure 5. French and Italian price projections according to the two price formation specifications: shocked €/$ exchange rate

The Italian price indeed overreacts to changes in French price formation, not only because price transmission is remarkably elastic, but even because the increase in the French price, induced by the US one, causes a positive response of domestic supply and a negative response of domestic demand, as expected, eventually generating an increase of French wheat self-sufficiency rate and, thus, of exports. All these indirect effects were considerably restrained in the exogenous price formation case, simply because the French price was "forced" to follow more strictly the intervention price, and to be less responsive to US wheat price changes.

6. Concluding remarks

Compared to other analogous large commodity market models (OECD-FAO, 2007), the AGMEMOD modelling approach has two major strengths. First of all, it includes many different cross-commodity and cross country linkages; therefore, it is inherently a complex model, fully capable of generating direct and indirect, trivial and non-trivial effects from external changes (for instance, change in policies, consumption patterns, external prices, etc.). Secondly, it is an econometric model, that is, its projections are driven by estimated parameters and consequently should be more consistent with historical evidence and observed data. At the same time, however, these main advantages also bring about relevant drawbacks. In particular, model performance with respect to external changes critically depends on how EU key-price formation is modelled and estimated. Linking the EU key-price to the world price by assuming the latter exogenous is not only implausible (the EU being, for most agricultural commodities, a major player in the world markets), but also makes model response to world price change, and to its interaction with price policies (namely, intervention prices), unsatisfactory.

In this paper, we propose an alternative way to model EU key-price formation by making the world (US) price itself endogenous. This is not achieved by explicitly modelling the commodity world market with the respective price formation, which could be theoretically challenging and computationally unaffordable. We merely model price formation through a system of dynamic simultaneous equations (a VECM), where long-run relations, as well as adjustments and short-run responses, among reciprocally dependent prices are admitted.

Projections generated within this alternative price formation show how relevant it may be in explaining price linkages and their indirect effects. At the same time, however, some further steps forward could be attempted. First of all, the current version of endogenous price formation excludes exogenous shifters, thus making prices almost invariant over time: introducing trends, dummies or other external prices would allow more dynamism in price formation. Secondly, further feedback effects from EU and world market performances (for instance, EU self-sufficiency rate as well as world excess supply) could also improve price formation complexity and, therefore, reliability of model projections. Finally, price policy

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itself (intervention prices, tariffs, etc.) could enter the current endogenous price formation in a more detailed and accurate way.

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ANNEX 1: The VECM estimation

In Listorti (2007), monthly French prices are collected from Eurostat, the same source AGMEMOD annual prices are taken from. As far as the intervention price is concerned, Listorti (2007) uses "single" prices, whereas in the AGMEMOD database "basic" prices are normally included. For the purposes of our analysis, "single" prices were put into the AGMEMOD database, but the differences don't affect the projections since they occur in years before the reference period. In Listorti (2007), US prices are obtained from the International Grains Council, and are FOB prices to which freight rates have been added. The US prices included in the AGMEMOD database (provided by FAPRI) are instead FOB ones. This difference is assumed not to influence the analysis.

In Listorti (2007), unit root tests (Augmented Dickey Fuller, Phillips Perron and Kwiatkowski, Phillips, Schmidt e Shin) have been run both on the French price and on the maximum between the intervention price and the US price expressed in logs, and in log-differences. Results overall confirmed that they are I(1) processes. The optimum lag-length for the VAR has been chosen according to the minimization of the Schwartz Bayesian Criterion up to a maximum of 25 lags, and, generally, was not affected by the deterministic trend chosen nor by the introduction of monthly dummies. The Johansen and Juselius procedure has been used to estimate the rank of the cointegrating matrix. Finally, the VECM was estimated in the "restricted constant" case, which allows for the presence of a constant in the cointegration relation (accounting for transaction costs) without having a trend in the levels of the data. Estimates are reported below.

	$\Delta p_{fr,t}$	$\Delta p_{w,t}$	Cointegration vector
α	-0.046**	0.053**	
$\Delta p_{fr,t-1}$	0.050	0.028	
$\Delta p_{w,t-1}$	0.025	0.226***	$p_{fr,t} = 0.289 + 0.921{*}{*}{*}\, p_{w,t}$
$\Delta p_{fr,t-12}$	0.475***	0.359	
$\Delta p_{w,t-12}$	-0.066	0.810	
D6	-0.009	-0.055***	
D7	-0.017*	-0.011	
D8	0	0.033***	

* 10% significance; ** 5% significance; ***1% significance.

$p_{fr,\ t-1}$ and $p_{w,t-1}$ are the French and the world price (i.e., the maximum between the US price and the intervention price), respectively. Monthly dummies (selected through specification tests) and the twelfth lag were introduced to remove autocorrelation from the residuals. The adjustments coefficients, α, a measure of the speed of price transmission, are both significant and have the right sign.

The $p_{w,t}$ coefficient in the cointegration vector can be read as the price transmission elasticity in the long run between the two price series, which should be equal to 1 in case of perfect validity of the LOP. This coefficient is indeed significant and very close to 1, though its interpretation brings some interpretative problems: they are mainly due to the fact that the intervention price plays a much bigger role before the 1990s. If the overall observation period is split into two parts, the nature of the relation found in the first one is very different from the general one, and no cointegration is found in the second sub-sample. We shouldn't also forget that the hypothesis required by the LOP (such as the existence of perfect competition, or those concerning transaction costs) are quite strict.

ANNEX 2: The current soft wheat price formation equation in the AGMEMOD model

The general form of the (1a) equation is $P_{i,k,t} = f\left(P_{i,w,t}, P_{i,\text{int},t}, v_{i,t}\right)$. For soft wheat, in the current AGMEMOD model we have that $P_{fr,t} = 46.25 + 0.16 P_{US,t} + 0.59 P_{\text{int}_t} - 0.16 TRQ_t + 0.003 SXL_t - 6.37 SSR_{fr,t}$ where $P_{fr,t}$ is the soft wheat French price (key-price) at time t, $P_{US,t}$ and $P_{\text{int},t}$ are the US (world) and intervention prices, respectively, TRQ_t is the tariff rate quota, SXL_t is the WTO subsidized quantity export limit and $SSR_{fr,t}$ is the self sufficiency rate for France.