Braunschweig 17.11.2008

#

AGMEMOD PARTNERSHIP

The AGMEMOD Tool Version 2.0 - Stylized Model Equations

Technical Paper No. 1| Petra Salamon

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The AGMEMOD model Version 2.0 stylized model equations

Introduction

The AGMEMOD model is an econometric, dynamic, multi-product PE model wherein a bottom-up approach is used. Based on a set of commodity specific model templates, country specific models were developed to reflect the detail of agriculture at MS level and at the same time allow for their combination in a EU model. Such an approach should capture the inherent heterogeneity of the agricultural systems existing across the EU, while the analytical consistency across the country models will be hold via a close adherence to templates. The maintenance of analytical consistency across the country models is essential for the aggregation towards a EU level, and also it facilitates the meaningful comparison of the impact of a policy change across different MS.

Within the 6th Framework Program, the AGMEMOD model has been turned into a EU combined model that comprises all Member States[1]. Since January 2008, this transformation of the framework from Version 1.0 to Version 2.0 can be characterized by:

- a transparent input–model–output structure;
- a consistent use of mnemonics, data and assumptions across countries;
- a memory saving use of variables;
- easy to extend with new commodities;
- easy to extend with new countries.

Further, the AGMEMOD Version 2.0 takes account of data and parameter up-dates up to the year 2020 for all MS.

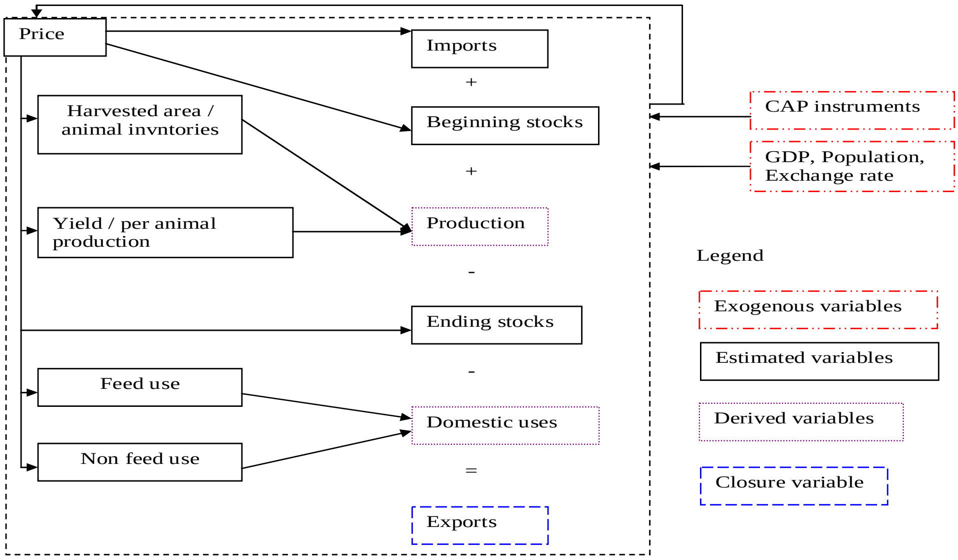
Also, in the first half of 2008 the milk and dairy product sector in AGMEMOD has been revised in order to assess the objectives of this dairy study. As a result, the dairy model structure in Version 2 changed significantly compared to the approach applied in Version 1 (Chantreuil et al, 2005). In the following the general layout of the templates used to model the commodity markets in AGMEMOD Version 2.

General commodity model structures

The overall template in AGMEMOD consists of different commodity market modules that should largely reflect the product coverage of each MS (Figure 1).

[1] The following Member states have been integrated in the EU AGMEMOD model: Austria, Belgium-Luxembourg, Bulgaria, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Netherlands, Poland, Portugal, Romania, Slovenia, Slovak Republic, Spain, Sweden and United Kingdom. Cyprus and Malta have not been included.

Figure 1: AGMEMOD commodity modelling structure



The crop commodity coverage ranges from cereals and oilseeds with their derived products (oils and cakes) to potatoes, sugar beets and sugar. The livestock commodity coverage consists of cattle, beef, pig, pig meat, poultry, eggs and sheep and goats. The dairy products covered are raw milk, whole milk, drinking milk, butter, SMP, cheese, WMP, cream and other fresh products. For each of these commodities, agricultural production, as well as market components such as supply, demand, trade, stocks and domestic prices, are derived by econometrically estimated equations. The relationship between the various agricultural commodities is reflected through substitution or complementarily elasticities in the modelled production or consumption relationships. More details can be found in Erjavec and Donnellan (2005) and Chantreuil et al (2005).

Crop model structure

In the crop models for grains, oilseeds and root crops, land is allocated in a two-step process. In the first step, producers' behaviour determines the total land area used for grains, oilseeds, and root crop culture groups (i). In the second step, the shares of the total land area devoted to the nested commodity groups (grains, oilseeds, and root crop cultures) are allocated for each culture j of the corresponding culture group (i).

The total area harvested equation for grains, oilseeds and root crops is written as:

$$ah_{i,t} = f\left(p_{i,t-1}^{j}, ah_{l,t-1}, V\right) \qquad j = 1,\dots,n; \quad i,l = 1,\dots,3; \quad i \neq l \qquad (1)$$

Where $ah_{i,t}$ is the area harvested in year t for culture group i, $p_{i,t-1}^{j}$ is the real price in year $t-1$ of culture j belonging to culture group i, and V is a vector of exogenous variables which could have an impact on the area of culture i that is harvested like e.g. , inter alia, the set aside rate, the rate of coupled premiums, etc..

The share of culture k belonging to the nest i ($sh_{i,t}^{k}$) is written as:

$$sh^k_{i,t} = f\left(p^j_{i,t-1}, sh^k_{i,t-1}\right) \qquad j, k = 1,\ldots, n \qquad (2)$$

The yield equation of culture k in the culture group i is written as:

$$r^k_{i,t} = f\left(p^j_{i,t-1}, r^k_{i,t-1}, V\right) \qquad j, k = 1,\ldots, n \qquad (3)$$

Where $r^k_{i,t}$ is the yield per hectare of culture k belonging to the culture group i, and V is a vector of variables which may impact on the yield per hectare of the culture j modelled. Income per hectare is not considered in the functional forms of the crop model supply side, which enables us to distinguish the price and compensation effects on producers' supply decisions.

For demand, in principle three uses are distinguished, namely crushing, feed demand and non-feed use (modelled on a per capita basis) by using the following general functional forms:

$$Fu^k_{i,t} = f\left(p^j_{i,t}, Z\right) \qquad j, k = 1,\ldots, n \qquad (4)$$

Where $Fu^k_{i,t}$ is the feed demand for culture k belonging to the culture group i and Z is a vector of endogenous variables, which could have an impact on the use considered.

$$NFu^k_{i,t} = f\left(p^j_{i,t}, NFu^k_{i,t-1}\right) \qquad j, k = 1,\ldots, n \qquad (5)$$

Where $NFu^k_{i,t}$ is the non-feed demand for culture k belonging to the culture group i.

Crushing of oilseed culture $_k$ ($CR^k_{i,t}$) is modelled as:

$$CR^k_{i,t} = f\left(cm^k_{i,t-1}, CR^k_{i,t-1}, V\right) \qquad k = 1,\ldots, n \qquad (6)$$

Where $cm^k_{i,t-1}$ is the real crushing margin of oilseed culture k. As it is planned to include the demand for bio-fuels in AGMEMOD Version 2.0, the equation (6) must be changed to

$$CR^k_{i,t} = f\left(\frac{DU^k_{i,t}}{XR^k_{i,t}}, V\right) \qquad k = 1,\ldots, n \qquad (6a)$$

where $XR^k_{i,t}$ is the extraction rate of oil of culture k and $DU^k_{i,t}$ comprises the oil demand of all usages including bio-fuels (for details see Von Ledebur et al, 2008).

Generally, stocks, export and import equations within the crop model have the following functional forms:

$$St^k_{i,t} = f\left(PR^k_{i,t}, DU^k_{i,t}, St^k_{i,t-1}\right) \qquad (7)$$

$$Ex^k_{i,t} = f\left(PR^k_{i,t}, DU^k_{i,t}, Ex^k_{i,t-1}\right) \qquad (8)$$

$$\mathrm{Im}^k_{i,t} = f\left(PR^k_{i,t}, DU^k_{i,t}, \mathrm{Im}^k_{i,t-1}\right) \qquad (9)$$

Where $\mathrm{Im}_{i,t}^{k}$, $Ex_{i,t}^{k}$ and $St_{i,t}^{k}$ are the ending stocks, exports and imports for culture k respectively, belonging to the culture group i in year t. $PR_{i,t}^{k}$ and $DU_{i,t}^{k}$ are the production and the total domestic use of culture k belonging to nest i.

Also, the respective markets for the processed commodities are included. The supply sides of these markets are provided for by crushed quantities and technical coefficients. The specification of equations for exports, imports, stocks, oil consumption per capita, industrial demand for oil and meal domestic use follow the approaches of equations (7), (8), and (9).

Livestock model structure

Similarly, the sub-models in the animal sectors follow a comparable structure. In general, the ending breeding stock numbers are modelled as[2]:

$$cct_{i,t} = f\left(cct^{k}_{i,t-1}, p_{i,t}, V\right) \qquad k = 1,\dots,n \qquad i = 1,\dots,n \tag{10}$$

Where $cct^{k}{}_{i,t-1}$ is the ending stock in year $t-1$ for the breeding animal type *k* delivery, $p_{i,t}$ is the real price in year t of the animal i, and V is a vector of exogenous variables which affect the ending stocks such as direct payments or specific national policy instruments.

Numbers of animals produced by the breeding stock is given by the following equation:

$$spr_{i,t} = f\left(cct_{i,t-1}, ypa_{i,t}\right) \qquad i = 1,\dots,n \tag{11}$$

Where $spr_{i,t}$ is the number of animals produced from the breeding herd $cct_{i,t}$ in year t and $ypa_{i,t}$ is the yield per animal concerned.

Within each animal culture i there can be m different categories of slaughtering j. The slaughtering of animal culture i in slaughter category j can be written as:

$$ktt_{i,t}^{j} = f\left(cct_{i,t}^{j}, p_{i,t}, z_{i,t}^{j}, V\right) \qquad i = 1,\dots,n \qquad j = 1,\dots,m \tag{12}$$

where $ktt_{i,t}^{j}$ is the number of slaughtering in category j of animal culture i in year t, $z_{i,t}^{j}$ is an endogenous variable that represents the share of the slaughtering in the different categories in the total number of slaughtering of the animal culture concerned, and V is a vector of exogenous variables.

The average slaughter weight per animal culture i can be written as:

$$slw_{i,t} = f\left(slw_{i,t-1}, z_{i,t}^{j}, p_{i,t}, V\right) \qquad i = 1,\dots,n\,. \qquad j = 1,\dots,m \tag{13}$$

To derive the total meat production of animal culture i the average slaughter weight is multiplied by the slaughtering, which is determined as:

[2] Depending on the country and the animal type regarded, the slaughtered animals and animal crops may be included as explanatory variables.

$$ktt_{i,t} = \sum_j ktt_{i,t}^j \qquad i = 1,\ldots,n. \qquad j = 1,\ldots,m \tag{14}$$

Total ending stocks of animals (breeding and non-breeding) and meat production are calculated as identities. Total domestic use of meat is calculated as the product of per capita demand times the exogenous population variable. Per capita consumption of meat itself is determined as:

$$upc_{i,t} = f\left(upc_{i,t-1}, p_{i,t}, p_{k,t}, gdpc_t, V\right) \qquad k,i = 1,\ldots,n;\ \ k \neq i \tag{15}$$

Where $upc_{i,t}$ is the per capita consumption of meat i in year t, $gdpc_t$ is the real per capita income and V is a vector of other exogenous variables that have an impact on per capita meat consumption. The functional form for estimating the ending stocks of meat has the same general form as the animal breeding inventories in equation (10). Furthermore, the specifications of the trade equations for animals and meat resemble the general functional forms used in the grains and oilseeds models in equations (7) to (9).

Dairy model structure

The dairy sub-model is more complicated due to the fact that the allocation of raw materials to dairy products is done on the basis of fat and protein rather than on the basis of raw milk. In the first step, raw milk production, raw milk imports and exports are determined. In the second step, raw milk for feed use and drinking milk consumption are estimated whereas the remaining raw milk is available for factory use (manufacturing milk) in the form of milk fat and milk protein for further processing. Governed by a series of equations, the usage of fat or protein itself determines the quantity of the respective dairy product manufactured. For the different commodities, the residual or balancing product uses are determined as they are in other markets by using equations (7)-(9) and (15).

Milk Supply

The milk yield per cow can be written as:

$$ypc_t = f\left(trend, (p/ici)_t, qua_t,\ V\right) \tag{16}$$

Where ypc_t is the yield per cow in year t, *trend* is a proxy for the technical progress, $(p/ici)_t$ is the real price/cost ratio of milk, qua_t is the exogenous milk quota allocated to the country concerned, and V is a vector of other exogenous variables that may affect milk yields per cow. The cow's milk production spr_t can be specified as

$$spr_t = f\left(qua_t, (p/ici)_t,\ V\right) \tag{17}$$

where spr_t is the cow milk production in year t, pwn_t is the price of milk in year t, ici_t is the milk production cost index, qua_t is the exogenous milk quota in year t allocated to the country concerned. This equation implies that producers will adjust their milk production according to changes of the milk quota. The pwn_t / ici_t variable means that changes in the profitability of the milk production influence the producer decisions to under-fill or overfill the quota. In case of a high milk production profitability, producers may overfill quota as an "insurance policy" to ensure that quotas will be filled; in case of low milk prices they may decide to under-fill the quota to avoid any over-quota milk production and the paying of any super-levy. The equation (17) was estimated or calibrated using the historical data.

Consequently, the dairy cow ending stock can be calculated as the cow's milk production divided by the milk yield per cow.

However, the milk production equation (17) cannot properly explain the consequences if main dairy policy reforms. For example, in practice, a sufficiently sharp reduction in support prices would result in a substantial under-fill of the quota. However, that effect cannot be captured by the used milk supply function so far.

A similar problem would arise when the milk price would decrease due to a quota expansion. In recent years and in some MS, milk policy reforms - mainly due to intervention support price reductions - resulted in a situation that the milk quota was not longer binding. Thus, a quota expansion will not inevitably be transformed into a production increase across all MS. In particular the quota was not binding in the MS that faced prices below the EU average levels over a succession of years. On the other hand, over the last ten years with particularly high prices, the milk quotas had been exceeded in other MS.

To model this phenomenon and to take account of the expected dairy policy reforms that would lead to significant changes in the milk productivity and milk quota rents, the milk production function in AGMEMOD needs to be extended.

Quota abolition

Under quota abolition, the main factor explaining the milk production is the profitability of the production, which can be proxied by the price-cost ratio and the quota rents. The milk quota abolition is expected to accelerate the structural changes in the dairy sector and this will lead to a rise in the efficiency gain. It is meant to indicate that efficiency gains have not occurred under the milk quota regime, but their effect has been to decrease production cost per unit and to increase quota rents. As the estimation of production costs on account data often takes enormous efforts, time series for costs or rents are mostly unavailable. Therefore, the yield per cow is partly incorporated in the milk supply equation and used as a proxy for efficiency gains. As a result, the milk production equation under quota abolition in AGMEMOD Version 2.0 has the following specification:

$$spr_t^{non\_quo} = f\left(pwn_t / ict_t, ypc_t\right) \tag{18}$$

where $spr_t^{non\_quo}$ is the milk production under the non-quota regime in year t, ict_t is the milk production cost in year t and ypc_t is the milk yield per cow in year t.

From 1984 onwards, the milk quota regime exerted its influence over milk production, processing, consumption and trade for OMS. Hence, an econometric approach based on estimates derived from historical data will not generate the correct effects of the policy switch that has been envisaged for dairy in the future. For this reason, the production function (18) is calibrated based on country-specific data on milk production costs and quota rents. This leads to a milk production increase when the quota will be abolished and the quota rent will disappear, except in those cases in which the quota rent is decreasing or has declined to zero.

Similarly, a synthetic production function needs to be applied in the NMS country models of AGMEMOD. Historical data observations for the countries that have acceded the EU since January 2004, mostly concern the non-quota period and thus describe a situation in which the milk had bee produced under typical - pre-accession - agricultural policy circumstances. As that policy situation was quite different from the current and future dairy policy environment in the NMS, the production equation (18) will also be implemented according to a synthetic approach. For both the OMS and NMS models, section 6.4 describes the calibration procedure applied in AGMEMOD Version 2.0.

Quota expansion

Prior to the milk quota abolition in 2014/15, a gradual quota expansion period has been envisaged. Potential significant reductions in the profitability of the milk production due to lower milk prices and/or cost increases and associated falls in the milk quota rents to zero will cause that the milk production equation (18) – used under the quota regime - will not be valid anymore. In this case, the farmer's behaviour is explained by the supply function used in the case of quota abolition. On the other hand, the quota expansion can still remain binding so that the production function used under the quota system is valid. Thus, both types of milk supply functions are applied for the quota expansion years and it is assumed that the lowest production level will determine the milk projections in each MS.

Finally, the milk production equation in the whole modelling period of the AGMEMOD Version 2.0 can be presented by combining the equations (17) and (18):

$$
\begin{aligned}
spr_t &= f\left(qua_t, pwn_t / ici_t\right) \cdot quo + spr_t^{non\_quo} \cdot nquo + \\
&\quad + \min\left(f\left(qua_t, pwn_t / ici_t\right), spr_t^{non\_quo}\right) \cdot (1 - quo - nquo)
\end{aligned}
\qquad (19)
$$

where quo is a dummy for the milk quota period and $nquo$ for the quota abolition period.

Milk Processing

As noted above, total milk production is allocated to three uses, namely feed use (ufe_t), fluid use (ufl_t), and factory use (ufa_t). Feed use of milk can be written as:

$$ufe_t = f\left(ufe_{t-1}, p_t, V\right) \qquad (20)$$

In which the fluid use is derived via the per capita fluid milk consumption multiplied by the population. The factory use of milk is derived to balance the total milk supply and use; it determines the available fat and protein supply used in the manufacturing sector. Here, a number of assumptions must be made concerning the fat and protein content of respectively raw milk and dairy commodities.

In the next step, the protein and fat are allocated to the different processing lines. For each final product either the fat or the protein content is estimated. E.g., if the protein content is estimated (e.g. protein used in cheese processing), the corresponding value defines the level of manufacturing (e.g. cheese produced) by an identity which reflects the fixed nature of the protein to fat ratio in that product. These ratios are calculated based on industry knowledge and expert judgement as part of the development of the dataset reflecting milk usage. Thus the quantity of cheese produced determines the amount of fat need in the production of cheese.

In principle, the protein allocation to a dairy commodity i can be written as as

$$ppc_{i,t} = f\left(ufa \cdot ppp\ , ppc_{i,t-1}, p_{i,t}, p_{k,t},\ V\right) \qquad i,k = 1,\ldots,n;\ \ i \neq k \qquad (21)$$

Where $ppp_{i,t}$ is the protein content in the raw milk delivered, $ppc_{i,t}$ is the allocation of protein to a dairy commodity *i* in year t, $p_{i,t}$ is the price of dairy commodity i, and V is a vector of exogenous variables that affect the protein allocation to commodity i. Total protein available is distributed directly or indirectly to n dairy commodities. However, only $n-1$ protein allocations will be estimated, as the allocation to the n^{th} product is determined as balancing residual. Consequently, the production of dairy commodity *i* including protein is calculated as the total milk protein use for commodity *i* divided by the protein content of the dairy commodity *i* which is a technical coefficient. The allocation of milk fat to other dairy products is determined in a similar way:

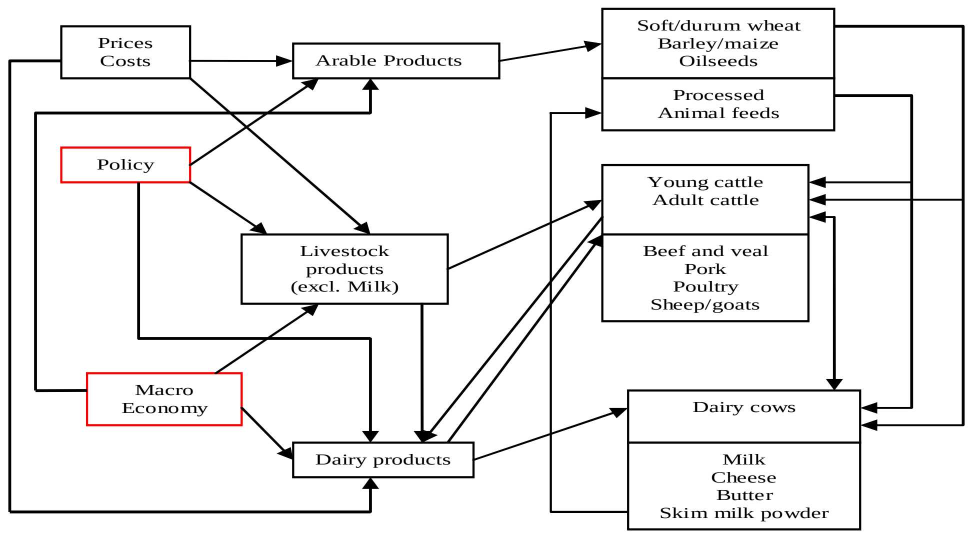
$$fpc_{i,t} = f\left(ufa \cdot fpp\ , fpc_{i,t-1}, p_{i,t}, p_{k,t},\ V\right) \qquad i,k = 1,\ldots,n;\ \ i \neq k \qquad (22)$$

Where $fpp_{i,t}$ is the fat content in the raw milk delivered, $fpc_{i,t}$ is the fat allocation to dairy commodity i, $p_{i,t}$ is the price of dairy commodity i, and V is a vector of exogenous variables that affect the fat allocation to commodity i. Given the allocation of milk fat to other dairy products or butter, the allocation of the remaining milk fat is derived from the milk fat supply and use identity.

Commodity linkages

The various domestic commodity markets are linked to each other by substitution or complementary parameters on the supply or demand side. Furthermore, interactions between the crops and livestock sub-models are captured via the derived demand for calves and feed. The supply and utilization balance is ensured via a closure variable (Figure 2). The choice of the closure variable may differ between one commodity sub-model and another and between one country and another. However, for most countries, the closure variable of the commodity markets is usually the exports variable. In general, sub-models capture supply, import, export, human and feed consumption, stocks and price relationships. These sub-models also cover a detailed set of agricultural policy instruments in each MS. Hence, the AGMEMOD tool developed allow for the generation of projections and scenario simulation results for each individual MS.

Figure 2: Linkage between commodity markets in AGMEMOD



To complete the building of the AGMEMOD sub-models tool for each of the commodities, it is necessary to add an equation that describes the equilibrium for each commodity market at both the MS and EU levels. This condition implies that production plus beginning stocks plus imports will be equal to domestic use plus ending stocks plus exports. In a closed economy, this supply and use equilibrium condition is sufficient to determine the equilibrium country market prices endogenously. Given that the model does not represent a closed economy, the Rest of the World can have important impacts on the economy modelled. To account for such impacts price linkage equations are used to represent the inter-relationship between MS, and between the EU and the Rest of the World.

When a country model market is not considered as the key market of the EU, the price linkage equations can be written as:

$$p_{i,t} = f\left(Kp_{i,t}, p_{i,t-1}, ssr_{i,t}, Kssr_{i,t}, V\right) \tag{23}$$

Where $p_{i,t}$ is the MS commodity *i* in year t, $Kp_{i,t}$ is the key price of culture *i* in year t, $ssr_{i,t}$ is the self sufficiency ratio (production divided by domestic use) for commodity *i* in the country concerned, $Kssr_{i,t}$ is the self sufficiency rate for the same commodity in the key price market, and V is a vector of exogenous variables which could have an additional impact on the national price.

When the national price is the key price, the price linkage equations used in the model can be written as:

$$Kp_{i,t} = f\left(Wp_{i,t}, EIp_{i,t}, Kp_{i,t-1}, Essr_{i,t}, V\right) \tag{24}$$

where $Wp_{i,t}$ is the corresponding world price, $EIp_{i,t}$ the corresponding European intervention price, $Essr_{i,t}$ is the EU self-sufficiency rate for commodity *i*, and *V* is a vector of variables which could affect the key price like exchange rates, tariff rate quota levels and subsidised export limits.

For each commodity market and for each country, the functional representation that is actually used can vary. In principle, such deviations from the template can be made by all country research teams. These deviations from the template are due to the requirement that the country level model should capture distinct market features at MS level. Where data limitations exist, the final functional forms are adjusted in response to the statistical and economic validation of the models. Accordingly, country-specific details can be found in e.g. Von Ledebur and Salamon (2005), Casado Garcia and Gracia Royo (2005), Chantreuil and Levert (2005), Esposti and Lobianco (2005), and Van Leeuwen and Tabeau (2005).