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Modelling of Land Use and Land Markets in Partial and General Equilibrium Models: The Current State

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Table of Contents

List of Tables

List of Figures

1 Introduction

Decoupling is probably the most commonly addressed issue in current modelling projects with respect to the agricultural sector of the EU. Economic researchers throughout the world are discussing various approaches to including the new CAP payment scheme in their quantitative models. Decoupling can be expected to have various and perhaps even contrary impacts on area allocation and agricultural production. On the one hand, decoupling of area payments could potentially lead to higher fodder supply, lower fodder prices and, in the end, higher supply of ruminant products. On the other hand, decoupling of payments for ruminants could result in lower supply and less demand for fodder. Moreover, it has also been argued that payments under the new CAP scheme would lead to substantial cuts of production or at least to a higher amount of voluntary set-aside area. To analyse the effects of decoupled direct payments, detailed links between various agricultural activities have to be captured by the model. In addition, an appropriate method of including decoupled payments in the model must be found.

This paper is the first deliverable for Workpackage 9 of the IDEMA project. It addresses the above mentioned issues by providing an overview of how different aspects concerning land use and land markets are modelled in selected partial equilibrium (PE) and general equilibrium (GE) models. The general criteria for inclusion of models in this review have been that the model in question should:

- have relevance for EU agriculture
- be multiregional
- be multicommodity in nature
- be currently or recently applied
- have documentation available

The application of these criteria has led to the following list of nine models, which is distinguished for PE and GE models:

Table 1: Partial Equilibrium Models Included in this Overview

Model	Location of development
AGLINK	OECD
CAPSIM	University of Bonn
ESIM	ERS/USDA, Stanford and Göttingen University
FAO WORLD FOOD MODEL	FAO
FAPRI EU-Missouri model	Iowa State University
PENN STATE TRADE MODEL	Pennsylvania State University
WATSIM	University of Bonn

Source: Own compilation.

Table 2: General Equilibrium Models Included in this Overview

Model	Modeller / Location of development
G-CUBED (Agriculture) model	McKibbin, Wilcoxen and Wang
GTAP	Purdue University

Source: Own compilation.

This paper is structured as follows: chapter two gives a general overview of the goals, applications, and characteristics of the selected models. Chapter three discusses various approaches of modelling crop supply, divided into three sections. In the first part, PE models are compared with regard to the way yield quantities and area allocation are calculated. GE models are treated in the second part, including a description of the model structure on the supply side which is embedded in a more generalised form and which describes the links between production and factor demand, as well as final commodity demand. The third part focuses on the assumption of land heterogeneity and how restricted land mobility is captured in different models. The OECD Policy Evaluation Model (PEM) is also taken into account as it is one of few models that treats land as a heterogeneous factor[1]. Chapter four captures the link between the livestock and crop/fodder sectors. As mentioned above, the way of modelling this link is crucial to illustrating the effects of decoupling on land allocation and production. Since the level of product disaggregation is a highly relevant indicator of how detailed decoupling effects can be analysed, a subsection provides a short overview of each model's commodity list. Chapter five compares different approaches of treating agricultural policy measures that affect land use including how coupled and decoupled payments are modelled, some results of studies that explicitly address decoupling effects, and how to depict mandatory and voluntary set aside. The paper closes with a summary and a preview of the next worksteps in Workpackage 9 of the IDEMA project.

[1] The PEM is not considered in other parts of the paper as detailed documentation was not available.

2 General Model Overview

This chapter provides a general overview of the goals, applications and main features of the models that are included in this review. As in other parts of the paper, PE and GE models will be treated separately. A summarised form of the following overview is presented in table 3 at the end of this chapter.

2.1 Partial Equilibrium Models

Before turning to the selected PE models, the design choices of a prototypical model shall be briefly described. This standard model will serve as a point of reference when describing the individual models. In the short description of each model only the nonstandard characteristics will be highlighted. However, model features that are related to land use are not mentioned here, but discussed in more detail in the following chapters.

For the purpose of this overview a standard PE model is assumed to have the following features:

- Scope: global coverage
- Factor markets and nonagricultural markets: exogenous
- Dynamics: comparative static
- Trade: homogeneous goods and pooled markets

The PE models mentioned in the introduction are presented in alphabetical order below.

AGLINK

AGLINK is a recursive dynamic supply and demand model of world agriculture. It was developed by the OECD Secretariat in close cooperation with its member countries, and is mainly used by various government services. The main purpose of the model is to analyse medium-term impacts of agricultural policies on agricultural markets and trade in OECD members. Dynamics are introduced by including lags in both endogenous and exogenous variables (van Tongeren and van Meijl, 1999). Meanwhile, the model consists of complete modules for more than 20 OECD and non-OECD member countries (Münch, 2004).

CAPSIM

CAPSIM was created in 1999 by the European Centre for Agriculture, Regional and Environmental Policy Research in Bonn and relies partly on its predecessor, the SPEL/EU Medium-term Forecasting and Simulation System. The model is designed for policy-relevant analysis of the CAP and covers the agricultural sector on a highly disaggregated level for 14 member states of the EU-15[2]. Simulations for the new EU member states can be run when connecting CAPSIM with the I-SIM satellite models. The land market is explicitly included. Furthermore, international prices or trade volumes are considered exogenous (EUROSTAT, forthcoming).

ESIM

The focus of the European Simulation Model (ESIM) is on effects of Eastern enlargement and analyses of CAP and WTO reform impacts on agricultural markets and budgetary expenditure. The model was initially developed by the Economic Research Service (ERS) of the United States Department of Agriculture (USDA) in cooperation with Timothy Josling (Stanford University) and Stefan Tangermann (Göttingen University) and first used in Tangermann and Josling (1994)[3]. Thereafter, the model was further developed by Tangermann and Münch (1995) as well as Münch (1995). Country coverage of ESIM was expanded twice by Münch (1997; 2002). The model has been updated and extended in terms of base period, product and country coverage, policy formulation and software platform (Banse et al., 2005)[4]. The updated version, which is considered in this paper, will cover 35 products plus voluntary set-aside area and 16 countries. As a special tool for analysing EU accession effects, the model places special emphasis on modelling accession countries' markets. Thus, besides the EU-15, the USA, Turkey and the Rest of the World, Cyprus, Malta, the 8 new member states from Central and Eastern Europe, plus Bulgaria and Romania are explicitly modelled in ESIM-GAMS.

FAO World Food Model

The FAO World Food Model aims at obtaining medium- and/or long-term projections and to simulate impacts of policy changes on agricultural markets. It was developed by the Commodities and Trade Division of the Food and Agriculture Organisation (FAO). In contrast to the standard model, dynamics have been introduced by adoption of a (Nerlovian) partial adjustment specification for the supply equations of some regions (e.g. EU-15) which use lagged prices to capture the dynamic decision process of crop and livestock production (van Tongeren and van Meijl, 1999).

FAPRI

Simulations with the FAPRI model are usually done by a set of various models that have been developed at the Food and Agricultural Policy Research Institute (FAPRI) at Iowa State

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2 Belgium and Luxembourg are combined.

3 As the authors of this paper are permanently working with ESIM at the University of Göttingen comments on and information regarding this model will not be cited in the whole paper.

4 ESIM has been rewritten into the GAMS software (Banse et al., 2005).

University. Each component of this set presents a specific theory structure and can be solved individually. The models focus on agricultural policy changes and other exogenous factors that affect US and world agriculture. Furthermore, FAPRI models belong to the group of dynamic models. This dynamic nature has been introduced by lagged variables for supply and demand functions. The countries/regions modelled greatly depend on the models chosen. For the purpose of this paper the FAPRI-Missouri EU model will be analysed (Westhoff, 2004; van Tongeren and van Meijl, 1999).

PENN STATE TRADE MODEL

The PENN STATE TRADE MODEL has been developed by ERS in cooperation with Penn State University. It is a gross trade model that accounts for total imports and total exports of each commodity in every region, but it does not distinguish a region's imports by their source or a region's exports by their destination. That is, commodities are treated as homogeneous. The PENN STATE TRADE MODEL is mainly used for policy analysing purposes within ERS. At present time, it includes the following 12 countries/regions, chosen for their importance for the agricultural situation of the United States: U.S., EU-15, Japan, Canada, Mexico, Brazil, Argentina, China, Australia, New Zealand, South Korea, and the Rest of the World (Stout and Abler, 2003).

WATSIM

The World Agricultural Trade Simulation Model (WATSIM) is developed by the University of Bonn. A comparative static version had been used until 2001. Meanwhile, the model has been redesigned and is now used as a quasi-dynamic model which solves on the basis of the trend-corrected results of the previous period. In addition, it has been transformed from a gross trade model using some kind of "pooled world market" into a model that reflects trade flows according to the Armington approach, in order to analyse the impact of trade policies on bilateral trade flows. The model's focus is on short-term to medium-term policy analyses as well as on long-term projections. The modified WATSIM contains 12 countries or regions, the latter aggregated according to similarities in policies or trade relations with the EU and not necessarily according to their geographical homogeneity (Kuhn, 2004; Kuhn, 2003).

2.2 General Equilibrium Models

As for PE models, some kind of prototype of the selected GE models shall first be defined before providing a short overview of the specific goals, applications and features of these models. Again, model characteristics relating to the land market are not captured here, but in the following chapters.

For the purpose of this overview a standard GE model is to have the following features:

- Scope: global coverage
- Factor markets and nonagricultural markets: endogenous

- Dynamics: comparative static
- Trade: Armington approach and bilateral trade relations

The specific goals, applications and features of the models are presented below.

G-CUBED (Agriculture)

The G-CUBED (Agriculture) model is an extension and a variation of the G-CUBED model developed by Warwick McKibbin and Peter Wilcoxen to include relatively detailed agricultural sectors and a country disaggregation relevant for key U.S. agricultural markets. The original G-CUBED model combines the disaggregated, econometrically-estimated, inter-temporal GE model of the U.S. economy by Jorgenson and Wilcoxen (1990) with the macroeconomic modelling approach of McKibbin and Sachs (1991). The G-CUBED (Agriculture) model focuses on impacts of international and domestic economic shocks on U.S. agriculture. Key applications have been the impact analysis of APEC trade liberalisation and the Asian economic crisis. A specific feature of the model is the imposition of intertemporal budget constraints on households, governments and nations. To accommodate these constraints, forward looking behaviour is incorporated in consumption and investment decisions (McKibbin and Wang, 1998; van Tongeren and van Meijl, 1999).

GTAP

The Global Trade Analysis Project (GTAP) model has been developed by a team led by Thomas W. Hertel at Purdue University. It particularly aims at analysing the effects of agricultural policies on commodity markets and trade. A special feature is the modelling of consumption expenditures through a nonhomothetic Constant Differences of Elasticities of Substitution demand system, which allows budget shares to vary with income. Furthermore, the model includes all quantitative restrictions as ad valorem prices wedges. Although not apparent in the standard model, other policies may also be explicitly incorporated into the framework. In addition to other models, imperfect competition assumptions can also be captured with the GTAP model (van Tongeren and van Meijl, 1999). However, by providing a detailed database, the GTAP project goes far beyond the pure construction of a model. In version 6.0 the database will cover 86 regions, 57 commodity groupings and 5 primary factors (land, skilled and unskilled labour, capital and national resources). Europe will be represented by country data for 32 individual countries/regions (GTAP, 2004). The database consists of country specific input-output data, bilateral trade statistics from the United Nations and protection data based on GATT information (Brockmeier and Salamon, 2004).

Table 3: General Overview of Partial and General Equilibrium Models

	General Description	Modelling of Trade	Goals and Key Applications
Standard Model	Comparative-static; global coverage; no factor markets included; policies as ad valorem price wedges	Homogeneous goods; pooled markets and net trade	
AGLINK	Recursive-dynamic; remaining features see standard	Standard	Analysis of the medium-term impact of agricultural policies on agricultural markets and trade in OECD members
CAPSIM	European coverage; land market included; remaining features see standard	International prices or trade volumes considered exogenous; remaining features see standard	Impact analysis of the CAP
ESIM	Standard	Standard	Impact analysis of enlargement on agricultural markets, trade and government budgets; impact analysis of agricultural policies
FAO WORLD FOOD MODEL	Recursive-dynamic; remaining features see standard	Standard	Simulation of medium- and long-term impacts of policy changes; contribution to the FAO outlook on markets of agricultural products
FAPRI	Recursive-dynamic; remaining features see standard	Standard	Analysis of agricultural policy changes and other exogenous factors that affect US and world agriculture
PENN STATE TRADE MODEL	Standard	Gross trade; remaining features see standard	Impact analysis of alternative proposals for agricultural trade liberalization (e.g. WTO reform) and agricultural policy reform
WATSIM	Quasi-dynamic	Armington, bilateral trade flows	Short-term shock analysis; medium-term projections and policy analysis; long-term projections and analysis of various shift factors (e.g. income and productivity)

Table 3: General Overview of Partial and General Equilibrium Models (cont'd)

	General Description	Modelling of Trade	Goals and Key Applications
G-CUBED (Agriculture)	Inter-temporal GE and macroeconomic model; factor markets included; remaining features see standard	Armington, bilateral trade flows	Analysis of impacts of international and domestic economic shocks on U.S. agriculture; key application the impact analysis of APEC trade liberalisation and the Asian economic crisis
GTAP Model	Factor markets included (default version); recursive-dynamic and imperfect competition version available; remaining features see standard	Armington, bilateral trade flows	Analysis of the effects of agricultural policies (e.g. CAP) on commodity markets and trade

Source: Own compilation.

3 Modelling Crop and Fodder Supply

3.1 Modelling Area Allocation and Yield Equations in Partial Equilibrium Models

In all of the selected PE models, supply of crops is modelled by multiplying a yield component by an area component, although in ESIM this is only valid for the European countries as non-European countries' crop supply is a direct function of own and cross producer prices as well as technical progress.

3.1.1 Yield Equations

The yield component of the supply function is captured quite differently in the models involved. In CAPSIM and, for cereals, in the FAO WORLD FOOD MODEL as well, yield is assumed to be exogenous and specified according to recent trends (for CAPSIM, see EUROSTAT, forthcoming; for the FAO WORLD FOOD MODEL, see FAO, 2001)[5]. In all other models it is captured as an endogenous variable, though still modelled in slightly different ways. In ESIM, yield is dependent on the own producer price, the price index of nonagricultural intermediate inputs and on a productivity shifter. In the PENN STATE TRADE MODEL, crop yield is modelled as a function of own producer yield price and the yield of the previous year. Unlike all other models, yield functions in the PENN STATE TRADE MODEL include partial adjustment factors which cause a short-run supply response that is some reduced proportion of the long-run response. The producer yield price is the price that producers receive at the margin for additional output. Normally the producer yield price would be the same as the producer price. However, the two may differ if government payments are based solely on area planted rather than on output. In such a case, the producer yield price would be less than the producer price because the producer yield price would exclude these government payments (Stout and Abler, 2003)[6].

In the FAPRI model yield equations are quite complex. These equations are a function of a trend defined by a moving average of own producer prices, and of area devoted to the crop in question and to all modelled crops. Area coefficients, therefore, have a negative sign, based on the assumption that all else equal, marginal hectares are less productive. The moving average of own producer prices for each projection period is a weighted average of the prices

5 If not explicitly mentioned, all information in this chapter regarding CAPSIM relates to EUROSTAT (forthcoming) and all information regarding the FAO WORLD FOOD MODEL relates to FAO (2001).

6 If not explicitly mentioned, all information in this chapter regarding the PENN STATE TRADE MODEL relate to Stout and Abler (2003).

of the previous 3 years. The weight is 0.5 on the most recent year, 0.3 on the previous year, and 0.2 on the year before that (Westhoff, 2004)[7].

In WATSIM yield is determined by own producer prices of the current and the previous period as well as by yield of the previous year. In AGLINK, yield depends on current own producer prices and a trend factor (for WATSIM, see Kuhn, 2003; for AGLINK, see OECD, 2002)[8]. However, the modellers of WATSIM expect yields to change very little when prices are changing; yield elasticities have been set at a uniform value of 0.1 for all crops. In ESIM, FAPRI, AGLINK and in the PENN STATE TRADE MODEL these elasticities are highly differentiated between crops and can have higher values.

Other than for cereals, the FAO WORLD FOOD MODEL determines the yield of oilseeds endogenously. In contrast to the above mentioned models, oilseed yields do not depend on the own producer price of the oilseed in question, but rather on the (lagged) producer prices of the related oil and oilmeal.

It can be stated that if producer prices of raw products are taken into account, yield is modelled as depending on own producer prices rather than on both own and cross producer prices. This procedure follows the argumentation that farmers decide on production in two stages: initially, they allocate the area in which the relative competitiveness of each crop is considered, then the intensity of production, that is the yield, depends only on the own price and input costs (Münch, 2002).

3.1.2 Area Allocation

The area component of the supply function is determined endogenously in each of the selected models. However, there are significant differences with regard to the design of area equations as well as the process of area allocation.

In ESIM area is allocated as a function of current own and cross prices, direct payments and a labour and capital cost index. Area allocation in WATSIM also depends on current own and cross prices and direct payments, but in contrast to ESIM, prices and subsidies as well as area of the previous year are also taken into account. The previous year is also considered in the FAO WORLD FOOD MODEL. In the case of cereals, area allocation depends only on lagged own and cross prices, on lagged area and on a trend growth factor. For oilseeds, area is simply a function of lagged prices of the related oil and oilmeal. Current prices and subsidies are not considered in this context (Yanagishima, 2004). As for its yield function, the PENN STATE

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7 If not explicitly mentioned, all information in this chapter regarding the FAPRI model relate to Westhoff (2004).

8 If not explicitly mentioned, all information in this chapter regarding WATSIM relate to Kuhn (2003) and all information regarding AGLINK relate to OECD (year unknown).

TRADE MODEL uses partial adjustment factors as well as a lagged area component in its area functions. Apart from the inclusion of that factor, the area function is very similar to those mentioned above. Payments, which are considered "coupled", are included in the producer prices.

The area allocation function used in CAPSIM is different from the functions described above. It is derived from a restricted normalised quadratic profit function. Dual values of the physical area and feed requirement restrictions are subtracted from revenues (per production activity) and input prices. The resulting net revenues of outputs and net prices of inputs are the explanatory variables of area allocation and herd size[9]. Revenues, in turn, are a function of producer prices and of 3 different types of payments. In contrast to all other models included in this review, the non-food production on set-aside area is also included in CAPSIM. It is assumed to remain constant in proportion to set-aside area and is a function of the area set aside multiplied by the rate of non-food production on area set aside in the base period.

In case of the FAPRI model, total area allocated to cereals and total area allocated to oilseeds is modelled separately.[10] Total cereal area is a function of weighted-average expected real gross returns, mandatory set-aside rate, and area used for major oilseeds. The weights simply reflect average historical shares of the various crops in total cereal area. For each commodity, expected gross returns are a function of trend yields, a weighted average of market prices from the past three years, and weighted expected payments (with lower weights on less coupled payments). As for market prices, prices are weighted as for yield allocation: 0.5 for the most recent year, 0.3 for the previous year, and 0.2 for the year before that. Once total area used for cereal production is determined, area is allocated to each cereal product based on expected market gross returns (excluding direct payments) relative to average expected market returns for all cereals. Area for oilseeds is determined in a similar manner, except that expected cereal returns are an argument in the total oilseed area equation.

The way of area allocation, which has been chosen in AGLINK, is similar to those of CAPSIM and FAPRI. Area allocation depends on own and cross commodity gross returns as well as on different kinds of payments weighted according to the degree of decoupling (von Lampe, 2004)[11].

While all models described in this section include area allocation to oilseeds and cereals, only ESIM and CAPSIM capture roughage products and voluntary set-aside area. Both models

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9 The method of modelling land price is described in the third part of this chapter where the assumption of heterogeneity of land is addressed.

10 In the FAPRI-Missouri EU model, no crops other than cereals and oilseeds are modelled.

11 The treatment of decoupled payments in the selected models is discussed in more detail in subsections 5.1 and 5.2.

treat silage maize and other fodder as endogenous variables. Grass and voluntary set aside are endogenous only in ESIM. However, area allocation elasticities are very low for these activities compared to other crops. This is because pasture is permanent pasture and the substitution for cropland is limited due to soil qualities and geographic/climatic conditions. The same holds for voluntary set aside, which for the most part comprises marginal land. Voluntary set aside is modelled as a quota product with the base period level being the quota and the shadow premium at 90 percent of the real premium. This is because set aside was restricted under Agenda 2000 to a maximum level per farm, and some farms reached that maximum.

In CAPSIM, grassland is treated as exogenous according to recent trends. Voluntary set aside is not modelled explicitly, but is taken into account in the function of the overall set aside area. More precisely, the overall set aside area function includes a set aside elasticity which ought to capture the opposite change in voluntary set aside usually accompanying an increase in the mandatory rate.

3.1.3 Variability of Total Area

As a result of drastically changing market prices, consumer habits or political conditions, land could potentially move into or fall out of production. However, in some models this land mobility is not taken into consideration. The exemptions are the FAPRI model, the PENN STATE TRADE MODEL, and the FAO WORLD FOOD MODEL. In addition to the individual crops of the model, the PENN STATE TRADE MODEL contains one land use residual category, which represents all other land that could potentially move into production of crops in the model, or absorb movements of land out of the crops in the model. For each region an assignment for a level of additional land is made, ranging from about 5 to 20 percent of total cropland, depending on the country/region. It should be noted that the one catch-all land category is de facto not part of the model and does not produce anything that is part of the model. Therefore, the amount of land in this category is not included and the cross-price elasticities associated with it are left out of the specification, as the model does not have a price for this category of land. One characteristic of the supply elasticity matrix of the model's remaining crops is that if the prices for all crops rise in the same proportion, there will be a slight increase in the area planted to each crop. Hence, total area would increase in this case (Stout and Abler, 2003). The solutions chosen in the FAPRI model and in the FAO WORLD FOOD MODEL are simpler than in the PENN STATE TRADE MODEL, since land can move into and out of production without further restrictions (for the FAO WORLD FOOD MODEL, see Yanagishima, 2004).

Independent of the design of area functions the process of area allocation normally leads to exceeding or undershooting the total available area if the model does not have an explicit market clearing condition for agricultural land. In order to ensure that all crop area is used for agricultural production (except set-aside area) ESIM, WATSIM and AGLINK use some kind of scaling process by which the sum of allocated area is scaled up or down according to total crop area available (for AGLINK, see von Lampe, 2004)[12].

For the EU a similar approach has been chosen for the PENN STATE TRADE MODEL, although only using a scaling down process. As mentioned above, in the PENN STATE TRADE MODEL land is allowed to move into or out of production. However, this is only true to a certain extent, since in the EU there is an upper limit to which land is allowed to move into production. If this limit is exceeded during the allocation process, the allocated area is scaled down until the limit is met. If the sum of allocated area is less than the limit, there is no scaling up process. For all other regions scaling up or down is not applied (Abler, 2004).

As for CAPSIM, allocated area is not scaled. Since the land market is endogenous, the rental price of land will induce adjustments in cropping activities so that area allocation is constrained by a market clearing condition. In this approach, scarcity of land, for example, would translate into rising rental value of land, declining net revenues of crops and reduced levels of crop activities, until the land balance is met.

As mentioned above, in the FAO WORLD FOOD MODEL and the FAPRI model the amount of land allocated to different activities is allowed to vary. This implies that the sum of the total allocated area is not scaled. However, in case of the European countries included in the FAPRI model, the elasticity of total area dedicated to different land uses with respect to weighted net returns is generally 0.1 or less. As regards the FAO WORLD FOOD MODEL, users at FAO argue that insufficient information regarding, for instance, multi-cropping practices do not permit establishment of a systematic link between total allocated and total available area (Yanagishima, 2004).

The total available area, where the sum of the allocated area is scaled is not constant in the selected models that use a scaling process. In fact, WATSIM and CAPSIM include trend projections for total available area in each of the modelled countries/regions. The standard procedure for trend projections is a simple linear trend on time, not dependent on other factors. In CAPSIM the ex post observations, which are necessary to calculate time trends, fall back on data from 1986 to 1999. As a result, total area is projected to decrease in most cases[13].

Although total available area is not related to the sum of allocated area in the FAO WORLD FOOD MODEL, it should be mentioned that it is changing over time. For some

[12] In ESIM, permanent pasture area is not scaled in order to allow for area falling out of production and to avoid compromising the cross compliance requirement of not converting pasture to cropland.

[13] For WATSIM, the period the observations relate to differs from case to case. For regions, for which no plausible trend estimation was possible, the trend has been left out completely.

countries/regions it is changing according to estimated trends, in others, it varies according to variables such as population and GDP, which in turn expresses the degree of urbanisation or conversion to non-agricultural uses of land (Yanagishima, 2004). In ESIM and AGLINK, total available area is assumed to stay constant over time (for AGLINK, see von Lampe, 2004)[14]. This is also true for the PENN STATE TRADE MODEL with regard to the base area in the EU (Stout, 2004).

The key model features regarding area allocation and yield functions are outlined in table 4 at the end of this chapter.

3.2 Structure of General Equilibrium Models

In GE models the supply of different agricultural sectors and other sectors of the economy is most often provided by firms. These firms interact with households and the government in many ways and on different levels. Of course, agents interact at the national and international levels[15].

The structure of product supply and factor demand is mostly defined within the scope of a "nested" production structure. All above mentioned characteristics of GE models are also true for the GTAP and the G-CUBED (Agriculture) model. In addition, both models rely on the assumptions of constant returns to scale, perfect competition and that firms maximise profit subject to a given technology. Moreover, input supply is assumed to be exogenous and completely mobile across different sectors of the economy. In the GTAP model, however, the mobility of land is constrained, which is addressed by a constant elasticity of transformation function (Brockmeier and Salamon, 2004). The issue of constraining land mobility will be discussed in section 3.3.

Figure 1 provides an illustration of a production structure that can be found in a very similar way in most GE models, including the GTAP and the G-CUBED (Agriculture) model.

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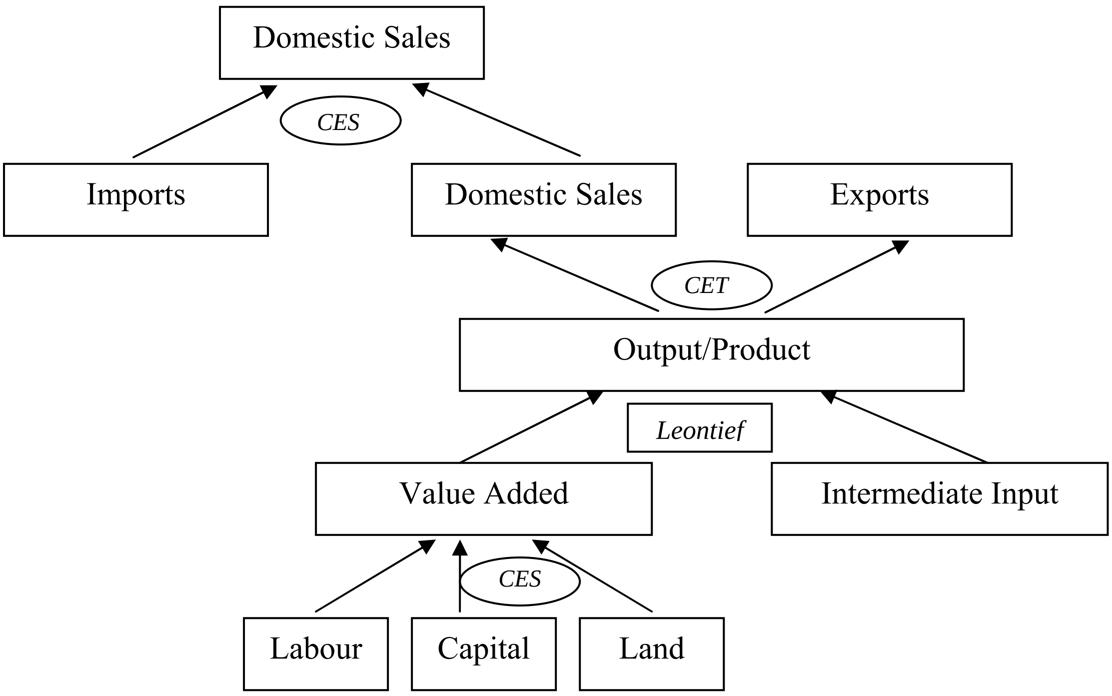
[14] ESIM, however, contains some kind of "land growth factor", though it is normally not activated.

[15] This is a simplified description. For a detailed description of interaction between agents in GE models, see, for example, Hertel (1997).

Figure 1: Nested Production Structure in General Equilibrium Models



Source: Derived from Banse (1996).

At the bottom of the inverted tree, the individual inputs, which are demanded by firms, are shown. Firms purchase primary factors, which normally consist of land, labour and capital. In the G-CUBED (Agriculture) model, for example, a fourth primary factor, energy, is included. Firms then use intermediate inputs, some of which are produced domestically and some of which are imported.

The manner in which firms combine individual inputs to produce their output depends largely on the assumptions on separability in production. Several GE models, such as the GTAP model, rely on the assumption that firms choose their optimal mix of primary factors independently of the prices of intermediate inputs and that substitution between primary factors and intermediate inputs is impossible[16]. This corresponds to the common assumption that the output/production nest in GE models relies on a Leontief production function. Since the level of output is also irrelevant in GE models owing to the assumption of constant returns to scale, this leaves only the relative prices of land, labour and capital as arguments in the firms' conditional demand equations for components of value added (McKibbin and Wang, 1998; Hertel, 1997).

The output sector of GE models is often modelled based on Leontief functions, although there is evidence of substitution between primary factors and some intermediates. The reason for

[16] In turn, the mix of intermediate inputs is also independent of the prices of primary factors.

proceeding this way is that substitution possibilities are not typical for all intermediates, and their proper treatment requires a more flexible production function than that underlying figure 1 (Hertel, 1997).

As for the G-CUBED (Agriculture) model, it is not clear from the documentation whether production relies on a Leontief function. Moreover, as intermediate inputs like feedstuffs are allowed to be substituted by primary factors like labour or capital one could assume that this is indeed not the case (McKibbin, 2004). However, as the degree of substitutability between primary factors and intermediate inputs is very limited and for many pairs of primary and intermediate inputs even zero, one could say that the underlying production function must be at least some kind of de facto Leontief function.

Within the primary factor branch of the production tree, elasticities of substitution between each pair of inputs are equal in many models. Modellers have to make this assumption of Constant Elasticity of Substitution (CES) as there is often not enough information available to include parameters based on econometric estimates (Hertel, 1997). The total amount of land, which is allocated to the different sectors, is fixed exogenously in both models. This implies that the land price has to adjust to guarantee market clearing for land, or if land prices are fixed, an amount of unused land will be calculated. In the GTAP model total available land is constant over time (Grinsted, 2004)[17], while total land varies relative to productivity growth in the economy in the G-CUBED (Agriculture) model (McKibbin, 2004). As land prices are endogenous to both models, clearing of land markets is guaranteed. That is, the total supply of land is always used given that land prices adjust to equilibrate the demand for land from each sector with the exogenous supply of land. Turning to the intermediate input nest of the production tree, the assumptions made in case of the primary factor nest hold here as well. That is, the mix of intermediate inputs does not depend on prices of primary factors (Hertel, 1997).

For each nest in the production tree two types of equations exist. One describes the substitutability of inputs within the nest. The second equation is the composite price equation that determines the unit cost for the composite goods produced by that branch. This price then enters the next higher nest in order to determine the demand for this composite (for the G-CUBED (Agriculture) model, see McKibbin and Wang, 1998; for the GTAP model, see Hertel, 1997). In the production/output nest, demand for composite value-added and for intermediate inputs is generated. The nature of equations used in this nest is of a somewhat different kind than in the nests described above. Since no substitutability between the value-added and intermediate is assumed, the relative price component drops out of the demand equation and relevant remains only the expansion effect (Hertel, 1997).

[17] A constant amount of total available land is at least true for all applications up to now. However, the amount of land could be changed exogenously as a reaction on certain policies.

As shown in the above figure, the overall output is sold either on the domestic or the world market. The distribution of commodities between both markets is described by a Constant Elasticity of Transformation (CET) function. Referring to the uppermost nest, final domestic demand is composed of domestically produced goods and imports. The substitutability between both components is again defined by a CES function (Banse, 1996).

The main characteristics of the selected GE models are summarised in table 4.

3.3 Area Allocation under the Heterogeneity of Land Assumption

For reasons of data availability it is very common in applied agricultural sector models to assume land as a homogeneous factor. However, this is not very realistic and embodies strong assumptions on price and elasticity of supply (Hertel, 1999). The capacity of a given plot of land to produce a particular farm product varies with climatic conditions, soil type and the location in the watershed. Since models based on the homogeneity assumption of land do not consider the natural conditions and constraints of certain regions and land types, they tend to overstate supply response (Gohin et al., 2000).

Therefore, some PE models assume a continuum of land types to address this issue. Lichtenberg (1989), for example, developed a framework for incorporating land quality into empirical studies of cropping patterns and technology choice[18]:

> "Land quality is assumed to be represented by a scalar measure q, which is normalised such that minimal land quality is zero and maximal land quality is one, i.e., $0 \leq q \leq 1$.
>
> G (q) represents the total acreage having quality at most q and $g(q) = G'(q)$ be the amount of acreage having quality q. It is further assumed that g(q) is continuous. Production is treated as having constant returns to land of any given quality. However, it is assumed to be neoclassical in all inputs and land quality. Therefore it can be represented by a restricted profit function, which is written as r^i (p_i,w,q), where p_i is the price of crop i and w is a vector of input prices. The per acre production function is assumed to be $f^i(x^i,q)$, with x^i as a vector of inputs used to produce crop i." (p. 188)

For simplicity reasons Lichtenberg (1989) considers the problem of allocating land between two technology combinations[19]:

> "$L_1(q)$ is assumed to be the proportion of land of quality q allocated to crop 1. If the farmer maximises profits, the relevant decision problem is to choose

---

18 See also Antle and Just (1990), who assumed a continuum of land types when modelling the interaction between environmental and agricultural policies.

19 However, extending the results to multiple crops is said to be straightforward (Lichtenberg, 1989).

$L_1(q)$ to max $\int_0^1 \{r^1(p_1, w, q)L_1(q) + r^2(p_2, w, q)[1 - L_1(q)]\}g(q)dq \quad \forall\, 0 \le q \le 1.$

The necessary conditions

$r^1(p_1, w, q) - r^2(p_2, w, q) \le 0$

imply that L_1 (q) = 1 if $r^1(q) > r^2(q)$ and $L_1(q) = 0$ otherwise; that is, that all land of quality q should be allocated to the most profitable crop. Thus, if it is profitable to grow both crops and the production functions of both crops are concave in land quality, each crop will be grown on a unique, compact range of land qualities. If crop 1 is grown on lower quality land, acreage planted to crop 1 will be

$$A_1 = \int_0^1 g(q)dg = G(q_1),$$

where q_1 is defined by

$r^1(p_1, w, q_1) = r^2(p_2, w, q_1)$,

and acreage allocated to crop 2 will be $A_2 = G(1) - G(q_1)$."

However, the heterogeneity of land assumption remains an exemption in PE models. In contrast to the majority of PE models, GE models often contain some kind of heterogeneity assumption and try to capture this feature in a tractable way. According to Gohin et al. (2000) three main approaches of including heterogeneity of land in GE models have been applied so far.

The first approach is based on the specification of migration functions that determine land flows between the various considered sectors. In Gohin et al. (2000) it is described in some detail. It is assumed that total available land may be broken down into different land types, so that all sectors face several land supply functions. Thereby, each type of land is more well-suited to the specific production process of the corresponding sector. However, land is not a specific factor for each sector since "land migration" between sectors is allowed. Due to this migration possibility, each land type supply function depends on the prices of all land types. The derived demand for each type of land, however, depends only on its own price[20].

The second approach has been developed by Robidoux et al. (1989) in their Canadian GE model. They assume different types of land, which can be substituted imperfectly in the production of a given agricultural good.

The third method is the specification of a transformation function, which takes total land as an input and distributes it among various sectors in response to relative rental rates. The standard

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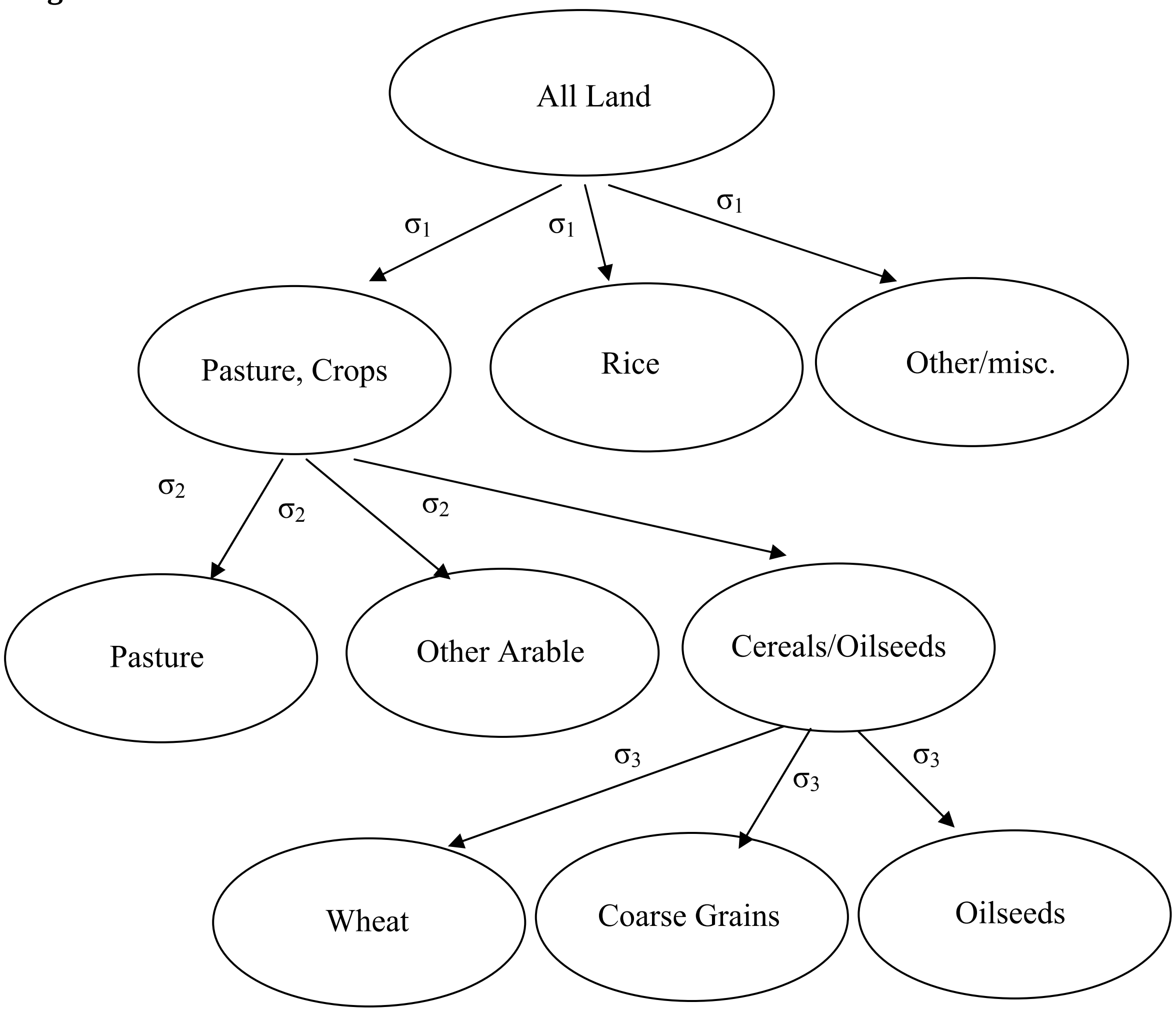
20 For further information regarding this approach of capturing heterogeneity of land see Gohin et al. (2000).

parametric function used in GE models is the CET function, where the elasticity of transformation is a synthetic measure of land heterogeneity.

A transformation function, which is used to capture different land qualities, is also part of the PEM (OECD, 2003) and the GTAP model (Brockmeier and Salamon, 2004), where land is assumed to be heterogeneous, but transformable between uses. In the following the land allocation structure, which is used in PEM, will be described in more detail:

Figure 2: Land Allocation Structure in the PEM



Source: Derived from OECD (2003).

Farmers act to maximise profits by allocating land across its possible uses according to a CET function which is assumed separable for different categories of uses such that land allocation takes place in successive steps. In the first stage, producers allocate land to rice, other agricultural uses as well as pasture and field crops. Second, the latter group of land uses is allocated between cereals and oilseeds, other arable uses and pasture. Finally, the cereals/oilseeds group is allocated between wheat, coarse grains and oilseeds. The parameter of the CET function determines the mobility of land between uses at each stage, thereby having the same value at each allocation stage and a higher value the more land becomes similar in the allocation framework. This kind of land allocation tree as applied in the PEM is shown in figure 2.

Within the scope of the models n this overview, CAPSIM is the only PE model, which treats land as a heterogeneous factor[21]. The following description of how this issue is modelled in CAPSIM is taken from EUROSTAT (forthcoming):

> "When calibrating the parameter in order to reproduce the base year, it is assumed that absolute price of land differs between different land uses. The idea of heterogeneity of land is adressed by introducing a parameter λ into the net revenue equation, which is written as follows:
>
> $\text{Net Revenue}_{m,j} = \text{Gross Revenue}_{m,j} - \lambda_{m,j} \cdot \text{Price of Land}_m$,
>
> with member state m and activity j. These relative land qualities λ are related to gross revenues relative to the soft wheat gross revenue as shown in the equation below:
>
> $\lambda_{m,j} = (\text{Gross Revenue}_{m,j} / \text{Gross Revenue}_{m,\text{soft wheat}})^{0,9}$
>
> The land price, which is an argument in the net revenue equation as well, is defined such that the smallest net revenue is 40 percent of the corresponding gross revenue. This approach ensures that all net revenues are still positive in the base year.
>
> The land price is calculated by solving the following equation:
>
> $\text{Net Revenue}_{m,min} = 0.4 \cdot \text{Gross Revenue}_{m,min} = \text{Gross Revenue}_{m,min} - \lambda_{m,j} \cdot \text{Price of Land}_m$
>
> Where $\text{Gross Revenue}_{m,min}$ is the smallest gross revenue observed in the member state."

21 In all other PE models as well as in the G-CUBED (Agriculture) model, land is treated as homogenous. However, some degree of land heterogeneity may be taken into account in several models by letting the cross price elasticities used in the acreage equations reflect the degree of substitutability of land between crops.

Table 4: Presentation of Yield and Area Allocation in PE and GE Models

	Yield	Area Allocation	Total Area
AGLINK	Function of own producer prices and a trend factor	Function of own and cross commodity gross returns and payments weighted according to the degree of decoupling	Allocated area scaled; total available area constant over time
CAPSIM	Exogenous; specified according to recent trends	Function of marginal profit relative to marginal net revenue; nonfood production on set-aside area also captured	Scaling not necessary; land prices induce adjustments of land supply and demand; total available area changing over time
ESIM	Function of own producer prices, costs of nonagricultural intermediates and technical progress	Function of own and cross prices, direct payments, capital costs, wages and obligatory set-aside; permanent pasture also captured	Allocated area scaled; total available area constant over time
FAO World Food Model	In case of cereals exogenous; for oilseeds a function of the producer prices of the related oil and oilmeal	Function of own and cross prices and a trend growth factor	No scaling process; land is allowed to move into/out off production
FAPRI	Function of a moving average of own producer prices, a trend factor, and areas devoted to the own and to all modelled crops	Total cereal (oilseed) area is a function of a weighted average of expected real gross returns, set aside and the area devoted to oilseeds (cereals); allocation of each cereal (oilseed) is a function of expected real market gross returns relative to average expected market returns for all cereals (oilseeds)	No scaling process; land is allowed to move into/out off production
PENN STATE TRADE MODEL	Function of own producer yield prices and partial adjustment factors	Function of own and cross prices (including coupled payments) and partial adjustment factors	Only process of scaling down in case of the EU, land is allowed to move into/out of production; base area in the EU is constant over time
WATSIM	Function of own producer prices	Function of own and cross prices as well as direct payments	Allocated area scaled; total available area changing over time

Table 4: Presentation of Yield and Area Allocation in PE and GE Models (cont'd)

	Yield	Area Allocation	Total Area
G-CUBED (Agriculture)	Production function; no specific yield function	Factor demand equations	Scaling not necessary; land prices induce adjustments of land supply and demand; total available area constant over time
GTAP Model	Production function; no specific yield function	Factor demand equations	Scaling not necessary; land prices induce adjustments of land supply and demand; total available area depends on productivity growth

Source: Own compilation.

4 Modelling the Effects of Coupled and Decoupled Payments

Decoupling is probably the most addressed issue in current modelling projects related to the agricultural sector of the EU. Decoupling can be expected to have effects on the composition of agricultural production in the EU. On the one hand, decoupling of area payments will increase the relative gross margins of non-Grandes Cultures (mainly fodder crops) compared to Grandes Cultures. This may shift fodder supply functions to the right, which could lead to lower fodder prices and potentially to higher ruminant supply. On the other hand, partial decoupling of payments for ruminants will probably reduce the gross margins of production which could lead to lower supply and less feed demand for fodder. This would lead to lower fodder prices and thus shift the supply functions for Grandes Cultures to the right. Thus, decoupling can be expected to have complex effects and the net effect on crop compared to fodder area is unclear.

To illustrate these effects various and detailed relationships between the crop and fodder sectors on the one hand and the livestock sector on the other hand have to be incorporated in the model structure. The following sections provide a short overview of how main aspects, which determine the effects of decoupling, are captured in those models presented above.

4.1 Modelling the Link Between the Livestock and the Fodder/Crop Sector

The most crucial questions when looking at the link between the livestock and the fodder/crop sector are if and how feed prices affect livestock production and how feed requirements are modelled. These questions shall be addressed in the following sections.

4.1.1 How do Feed Prices Determine Livestock Production?

In the FAPRI model, a ratio of output prices and weighted payments (with lower weights on less coupled payments) to input prices is used to determine livestock production. Each of the major feeds is weighted by its share in the base ration for the animal in question (Westhoff, 2004). In the PENN STATE TRADE MODEL livestock production depends on own and cross livestock prices, direct payments, and on a feed cost index for the considered animal product. This feed cost index is a weighted average of feed prices, using the base period feed component mix as constant weights (Stout and Abler, 2003). This is almost the same for AGLINK (von Lampe, 2004) and ESIM. In these models supply of animal products is a function of effective own and cross prices (including premiums) as well as a feed cost index and, in case of ESIM, prices for other inputs. However, the feed component mix is not fixed, but flexible according to the own and cross price elasticities of feedstuffs. In WATSIM, livestock production does not depend on a feed cost index, but on single own and cross feed prices, and in addition on own and cross prices of animal products (Kuhn, 2003).

In case of the FAO WORLD FOOD MODEL, livestock production depends on own and cross livestock prices as well as on an average feed price. This, in turn, is an average of feed prices weighted by the total amount of each feed product that is used in overall livestock production (FAO, 2001)[22]. In CAPSIM, livestock production depends on individual market prices for feed, however, corrected by the shadow prices for energy and protein (Witzke, 2005)[23].

In GE models the link between the livestock and the fodder or crops sector is most often not modelled as detailed as in PE models. However, as all types of feed belong to the inputs, which are used in livestock production, in the G-CUBED (Agriculture) as well as the GTAP model, feed prices determine livestock production. Thereby, the change of quantity in animal production depends on the share of the feed type in question in the total inputs (for the G-CUBED (Agriculture) model, see McKibbin 2004, for the GTAP-model, see Hertel, 1997). A summary of the main aspects discussed in this section can be found in table 5.

4.1.2 How is Feed Requirement of Livestock Production Modelled?

In AGLINK, ESIM, the PENN STATE TRADE MODEL, the FAPRI model and the FAO WORLD FOOD MODEL, feed demand is determined by own and cross feed prices and by the level of livestock production. This implies that feed components can be substituted. However, different types of feedstuffs cannot be substituted freely. In fact, own and cross price elasticities imply certain protein and energy content requirements, which affect the degree of substitutability among different feeds and the response of livestock supply to changes in feed prices. In the FAPRI model negative own price elasticities of feed demand are slightly larger in absolute terms than the sum of the cross price elasticities. Implicitly, it is suggested that livestock producers can substitute other feedstuffs (e.g., cereal substitutes, forage) for cereals and oilseeds. Except for AGLINK and the FAO WORLD FOOD MODEL, in all models, feed composition is reflected for each type of livestock product. In ESIM, for example, feed demand is defined per animal output unit and for each of the animal products. Total feed demand is defined as the sum over animals of feed demand per animal unit multiplied by animal production. In AGLINK and the FAO WORLD FOOD MODEL, feed composition relates to an aggregate of all animal products (for AGLINK, see von Lampe, 2004). In the FAO WORLD FOOD MODEL feed demand for milled rice is a function of own and cross prices as well as of the total milled rice production.

In CAPSIM a different approach has been chosen as regards modelling of feed demand. In this model, feed demand depends on market prices for individual feeds corrected by the shadow prices for energy and protein. More precisely, if the price of a certain feedstuff increases and the demand accordingly decreases, nutrient balances ensure that neither an energy nor a protein deficit can materialise. This is because shadow prices for protein and/or energy rise whenever the required quantity of protein and/or energy is not provided. On the

22 Eggs are not explicitly captured in the documentation of the FAO WORLD FOOD MODEL.

23 For more information, see below.

one hand, the increase in these shadow prices would moderate the increase in the net price of the feedstuff in question, which is the market price minus the nutrient shadow prices. On the other hand, it would trigger a moderate decrease in the price of other nutrient rich feedstuffs. As a consequence reallocation in feed demand would tend to maintain the nutrient balance (Witzke, 2005). A similar approach is applied in WATSIM, though it only includes an energy balance instead of both an energy and a protein balance (Kuhn, 2004)[24].

As mentioned above, in GE models the link between livestock and fodder or crops is often modelled much more simply than in PE models. In the G-CUBED (Agriculture) model, for example, the livestock sector and the sector of feed products are represented by aggregates named "livestock products" and "feed grains" respectively. However, given this model structure, it is still possible to illustrate some kind of expansion effect, i.e., the quantity of feed grains reacts on changes in the production of livestock products. In addition, demand of feed grains can also change when the price of feed grains is changing since this input into livestock production can be substituted by other inputs like capital and labour (McKibbin, 2004). Table 5 summarises the most important model characteristics presented in this section.

[24] It should be mentioned that milk is also captured as feed in two models. In ESIM, feed demand for milk is a linear transformation of milk supply; in the FAO WORLD FOOD MODEL it is a function of the number of milking cows and the producer price index of milk (FAO, 2001). In the remaining models feed use of milk is not explicitly covered.

Table 5: The Link Between the Livestock and the Fodder/Crop Sector

	Feed Prices as Determinants of Livestock Production	**Feed Requirement**
AGLINK	Feed cost index with flexible components weighted by the total amount of each feedstuff used in overall livestock production	Determined by own and cross feed prices and by the level of livestock production; feed composition relates to an aggregate of all animal products
CAPSIM	Feed prices not in the livestock production function	Feed demand based on a protein and energy balance
ESIM	Feed cost index with flexible components unique for each livestock product	Determined by own and cross feed prices and by the level of livestock production; feed composition reflected for each livestock product
FAO World Food Model	Feed cost index weighted by the total amount of each feedstuff used in overall livestock production	Determined by own and cross feed prices and by the level of livestock production; feed composition relates to an aggregate of all animal products
FAPRI	A ratio of output to input prices is used to determine livestock production; feeds weighted by their shares in base ration for each animal product	Determined by own and cross feed prices and by the level of livestock production; feed composition reflected for each livestock product
PENN STATE TRADE MODEL	Feed cost index with constant components unique for each livestock product	Determined by own and cross feed prices and by the level of livestock production; feed composition reflected for each livestock product
WATSIM	Own and cross feed prices used to determine livestock production	Feed demand based on an energy balance
G-CUBED (Agriculture)	Costs of each feed type as a share of total input costs	Livestock and feed sector highly aggregated; illustration of expansion effect
GTAP Model	Costs of each feed type as a share of total input costs	No information available

Source: Own compilation.

4.2 Product Coverage

As mentioned above, in order to illustrate the impacts that decoupling could have on area allocation, a strong and well defined link between the crop and fodder sector on the one hand and the livestock sector on the other must be included in the model structure.

Of course, a precondition of illustrating decoupling effects in much detail is that the list of feed products, which are captured in a model, contains not only feed grains and oilseeds, but also pure fodder crops. This, however, is only true for ESIM and CAPSIM (EUROSTAT, forthcoming). Both of these models are able to illustrate changes in production and feed requirement of silage maize, grass and a third category of fodder called "other fodder". Although some other models also include a long list of products, which are fed to animals, they do not explicitly contain pure fodder crops. This is also true for the GE models GTAP and G-cubed, though in the latter only four agricultural sectors are included, which are highly aggregated. In case of AGLINK, however, changes in area of the residual category called "pasture and fodder", which reacts to changes in total cereal and oilseed area, could be interpreted as a change in area used for fodder production. A detailed list of agricultural commodities captured in the different models is shown in table 6.

Table 6: Agricultural Products Covered by the Selected Models

	Products/Sectors
AGLINK	Wheat, barley, maize, oats, rice, soybean, sunflower seed, rapeseed, oilseed meals, oilseed oils, palm oil, vegetable oil, corn gluten feed, manioc, milk, fresh dairy products, butter, cheese, skimmed milk powder, whole milk powder, casein, whey powder, concentrated milk, beef and veal, pig meat, poultry meat, sheep meat, eggs, and wool
CAPSIM	Soft wheat, durum, barley, maize, other cereals, pulses, potatoes, sunflower seed, soybeans, rapeseed, silage maize, grass, other fodder, meal and oil of rapeseed, sunflower seed, soybeans and olives, feed rich protein imported, feed rich energy imported, sugar, textiles and industrial crops, vegetables, fruit, wine, other final crop products, cow and buffalo milk, sheep and goat milk, butter, beef and veal, pig meat, poultry meat, sheep and goat meat, young calves male and female, eggs, other animal products, molasses, skimmed milk powder, cheese, other products of milk, milled rice
ESIM	Soft wheat, durum, barley, rye, rice, maize, other cereals, potatoes, manioc, sunflower seed, soybeans, rapeseed, silage maize, grass, other fodder, meal and oil of rapeseed, sunflower seed, and soybeans, corn gluten feed, other energy, other protein, sugar, milk, butter, skimmed milk powder, cheese, beef, pig meat, poultry meat, sheep meat, eggs,
FAO World Food Model	Wheat, millet sorghum, maize, other coarse grains, rice, sunflower seed, soybeans, rapeseed, cottonseed, groundnuts, linseed, meal and oil of rapeseed, sunflower seed, soybeans, cottonseed, groundnuts, linseed, palm kernels, other vegetables and fish, oil of olives and coconuts, cow milk, other milk, butter, beef and veal, pig meat, poultry meat, sheep meat, lard and tallow

Table 6: Agricultural Products Covered by the Selected Models (cont'd)

	Products/Sectors
FAPRI	Soft wheat, durum, maize, barley, rye, rice, rapeseed, sunflower seed and soybeans.
PENN STATE TRADE MODEL	Wheat, maize, other coarse grains, rice, soybeans, sunflower seed, rapeseed, cottonseed, peanuts, other oilseeds, oil and meal of soybeans, sunflower seed, rapeseed, cottonseed, peanuts, other oilseeds, tropical oils, cotton, sugar, beef, pig meat, poultry meat, milk, butter, cheese, skimmed and whole milk powder, other dairy products
WATSIM	Wheat, barley, maize, other cereals, rice, starch crops, soybeans, rapeseed, sunflower seed, other oilseeds, oil and meal of soybeans, rapeseed, sunflower seed, other oilseeds pulses, sugar, milk, butter/cream, cheese, skimmed milk powder, beef, pig meat, poultry meat, meat of other origin, eggs
G-CUBED (Agriculture)	Food grains, feed grains, nongrain crops, livestock products
GTAP model	Wheat, cereal grains, paddy rice, aggregate of vegetables, fruits and nuts, oilseeds, sugar, plant based fibers, vegetable oils and fats, other crops, aggregate of bovine cattle, sheep and goats and horses, bovine meat products, other meat products, other animal products, milk, dairy products, processed rice, other food products, beverages and tobacco, wool

Source: OECD (2002), EUROSTAT (forthcoming), FAO (2001), Westhoff (2004), Stout and Abler (2003), Kuhn (2003), McKibbin and Wang (1998), GTAP (2004).

5 Modelling Agricultural Policies

5.1 Approaches of Modelling Coupled and Decoupled Payments

There have been discussions among economists about the potential impact of the new CAP payments on agricultural production. It is often argued that decoupled payments lead to increasing wealth levels, to less capital constraints, and to higher production by risk averse producers (Burfisher and Hopkins, 2003). According to a study conducted with the PEM decoupled payments still provide some production incentive equivalent to 3 percent of the impact market price support has on production (OECD, 2003). This chapter provides a short overview of how coupled and decoupled payments are treated in the models.

FAPRI captures direct payments as expected payments; they are one argument in the expected gross returns function, which in turn is a determinant of the total Grandes Cultures area function (Westhoff, 2004). The production effectiveness of the new payments is taken into account by implementing a decoupling factor. This factor weights direct payments according to their assumed impact on production. AGLINK also uses a decoupling factor when depicting the new payments[25]. These payments are a variable of the return function (von Lampe, 2004)[26]. In ESIM and WATSIM direct payments enter the area allocation functions like prices, i.e., market price and direct payment per product unit make up for an "effective market price" which is the explaining variable (for WATSIM, see Kuhn, 2003). A decoupling factor could also be easily introduced.

In CAPSIM, the new payments are represented as a homogeneous land premium given to all agricultural land within each country (Witzke, 2004). As mentioned in section 3.1, direct payments determine, among other factors, the area allocation by influencing the gross revenue and net revenue function. As in all above mentioned models, direct payments in the PENN STATE TRADE MODEL are an explaining variable of area allocation. However, in this model payments under the new CAP scheme are not yet captured. The old EU compensatory payments are considered to be neither completely coupled nor decoupled as the EU requires farmers to plant (but not necessarily to harvest) a crop to receive the payments. As a result only 50 percent of the compensatory payments for Grandes Cultures and milk as well as 50 percent of the set-aside premium for all Grandes Cultures and cotton are captured as coupled payments in the PENN STATE TRADE MODEL. The second half of these payments is assumed to have no effect on producer prices and thus is excluded. Headage payments and suckler cow premiums, in contrast, are treated as fully coupled (Stout and Abler, 2003). In the GTAP model market price support measured as the market price support component of the

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25 Information on the specific value of the decoupling factor have not been available for most models other than the FAPRI model. However, it should be possible to change this value for specific purposes.

26 Decoupling rates used in AGLINK are obtained from PEM simulations.

OECD Producer Support Estimate is modelled as a product price wedge. Area payments are modelled as wedges between the return on land in crop production and what the return area earns in alternative uses. Decoupled payments are modelled similar to area payments, though in case of decoupled payments the wedge is equal across all crops and most other uses of arable land. In the G-CUBED (Agriculture) model policies affecting land use, like direct payments, are not captured at all (McKibbin, 2004).

5.2 Simulation Results

In recent studies, some of the models presented in this paper have already been used to simulate effects of decoupled payments on agricultural production and area allocation. The following section describes how decoupled payments are included in the models. The applied approaches explained in section 5.1 are addressed again and described in some more detail. Next, some simulation results regarding the impact of decoupled payments on production and area allocation are presented.

All studies in this section using PE models analyse the impact of the Mid-Term-Review (MTR) proposals in July 2002. The key findings of these studies have been brought together in a publication of the European Commission in 2003. The GTAP model was applied in a study of the Danish Research Institute for Food Economics simulating the effects of decoupling (Frandsen et al., 2003).

In the study using ESIM, decoupled payments were considered as lump sum payments with no impact on production. Direct payments have been completely removed from the relevant behavioural equations and no decoupling factor has been applied.

As mentioned above, the FAPRI model relies on the assumption that even the decoupled payments have some impact on farmers' production decisions. For the analysis of the MTR, payments are treated as having 30 percent of the production influencing effect of the subsidies they replace (European Commission, 2003a).

CAPSIM treats the Single Farm Payment as a uniform payment at national or regional level, i.e. a uniform noncrop-specific coupled payment. The way of calculating the exact value of these payments is quite complex (European Commission, 2003a):

1. The premiums for cattle, sheep and arable crops, which have been paid under the Agenda 2000 regime, have been aggregated to a total available premium volume.
2. In the second step, this volume has been increased according to the 50% compensation for the price cut in cereals, which amounts to 7.5%. Afterwards it has been decreased to reflect the drop in the durum wheat premium for traditional areas to 250 EUR/ha.
3. The payments of different types (arable, beef, dairy, and sheep) have been reduced according to the modulation proposal by 18% for that part of the premium volume, which is affected by modulation. This part has been estimated in the Commission

based on FADN data and is on average about 66% such that the payments have been reduced by about 12% due to modulation.

4. In the fourth step, the reduced payment volume has been converted into a uniform premium for eligible “MTR crops”, which are all crops except fruits, vegetables, olives, wine, and other crops including nurseries.
5. As historically based entitlements can not be increased by, for example, reducing vegetables in favour of cereals, the eligible area has been put under some sort of ceiling.

In order to take the cross compliance requirements into account, CAPSIM relies on the assumption that the conversion of former grassland into fallow land or set aside is prevented such that the grassland area has been taken to be unaffected by the MTR proposals (European Commission, 2003a).

In the study using the GTAP model, decoupling is addressed in a somewhat broader sense, i.e. the study analyses the impacts of decoupling all kinds of payments including output premiums, intermediate input subsidies, and land- and capital-based payments. As mentioned above, decoupled payments are captured by converting these payments into a region specific homogeneous payment to land irrespective of the use of the predefined and fixed agricultural area (Frandsen et al., 2003).[27]

The studies mentioned above are different with respect to the level of disaggregation when illustrating the effects of new policy measures. While the studies using the FAPRI model and CAPSIM only show the aggregate effect of the implementation of all MTR measures (including decoupling and price cuts), the study using the GTAP model focuses on the isolated impact of decoupled payments, aside from MTR effects, while the study using ESIM illustrates both the aggregated effect of the MTR and the isolated impact of decoupling.

An isolated analysis of decoupled payments without any further changes in policies would enable identifying the pure decoupling effect. Most studies, however, analyse the consequences of the MTR by adjusting both the protection level for different commodities as well as the degree of coupledness of EU direct payments. Therefore, the results of these studies allow drawing only limited conclusions regarding the isolated effects of decoupled payments.

The studies conducted with ESIM, CAPSIM, and FAPRI analyse the impact of the MTR by comparing the results of the MTR with a reference scenario which is a continuation of the Agenda 2000. The results of these three studies are summarised below.

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[27] Information on how this uniform payment is obtained is unavailable.

In all models the MTR is projected to reduce total cereal area with rye and durum wheat as the most affected crops. The area allocated to cereals under the continuation of Agenda 2000 could potentially be cultivated by energy crops or voluntarily set aside under the MTR scenario. The negative impact of the reduction in cereal area on total cereal supply could be partly compensated by higher projected growth in yields. Different and even contradictory results have been obtained with respect to the development of the oilseed area and production. While CAPSIM projects an increase of oilseed area by 1.5 %, FAPRI expects a decrease of 3.7 % (European Commission, 2003a). These models estimate beef and sheep production would decline by 3 to 8 percent and 3 to 6 percent respectively. Silage area would be reduced compared to Agenda 2000 levels due to the decline in beef production, greater incentives to shift towards a more extensive livestock production and towards other arable fodder which becomes eligible for payments within the scope of the MTR (European Commission, 2003a).

After the main effects of the entire MTR package on agricultural production and land use have been described above, the focus in the following will be on summarising the results regarding the isolated impact of decoupling payments. Here the studies using the GTAP and ESIM models will be considered.

In the study using ESIM, a "market" scenario, which includes the MTR proposals for market measures and set aside, is compared with a scenario called "market + decoupling", which simulates effects of market measures and decoupling of direct payments (arable crops, beef, and milk). This procedure allows identifying the effects of decoupling in comparison to the other elements of the MTR proposals. The results of both scenario runs relate to the projected year 2009 and their differences can be summarised as follows.

Compared to the market scenario decoupling would reduce area of cereals by 1.2 mill. ha or 3.3 percent. Cereals production, however, is projected to decline by just 0.8 percent due to slightly increasing yields. Specifically, wheat production is projected to decline by 1.2 percent with area decreasing by 3.8 percent and yields increasing by 3.2 percent. For rye, production would decrease significantly by about 24 percent due to a strong decrease in area (European Commission, 2003a).

The implementation of the decoupling scheme would have a significant impact on the beef sector, where production would drop by 7.3 percent in comparison to the scenario without decoupling.

For a summary of the effects of decoupling on the area use, yield and production of selected products see table 7.

Table 7: Effects of Decoupling on Area, Yield, and Production, EU-15, ESIM Results

	Market	Market + decoupling	% deviation from market
Cereals			
Production (mill. t)	221.6	219.8	-0.8
Area (mill. ha)	36.5	35.3	-3.3
Yield (t/ha)	6.1	6.2	+1.6
Wheat			
Production (mill. t)	115.1	113.7	-1.2
Area (mill. ha)	18.3	17.6	-3.8
Yield (t/ha)	6.3	6.5	+3.2
Rye			
Production (mill. t)	4.6	3.5	-23.9
Area (mill. ha)	1.2	0.9	-25.0
Yield (t/ha)	3.8	3.8	0.0
Beef			
Production (mill. t)	7.8	7.3	-7.3

Source: European Commission (2003a).

As described above, in the study using the GTAP model decoupled payments are modelled by converting all domestic support in each member state into a uniform hectare payment given to all agricultural land (i.e. no budgetary savings). When expressed in terms of a deviation from a status quo scenario corresponding to the continuation of Agenda 2000, the main results of decoupling, which relate to the projection year 2013, are as follows.

The production of cereals is projected to decrease strongly by almost 7 percent in case of wheat and 5.6 percent for other grains. Oilseed production would even drop by 9 percent and bovine meat production by 10.8 percent when direct payments are decoupled (Frandsen et al., 2003). The simulation results of this study are summarised in table 8.

Table 8: Supply Response to Decoupling of Payments, EU-15, GTAP Model Results

	Base scenario: Continuation of Agenda 2000 (Index)	Decoupling (deviation from base scenario in percent)
Wheat	100	- 6.9
Other grains	100	- 5.5
Oilseeds	100	- 9.0
Bovine meat products	100	- 10.8

Source: Frandsen et al. (2003).

The results show that cereal area and production would decline when direct payments are decoupled. Durum wheat and rye seem to be the most affected crops. Beef production would experience a strong drop as well. Contradictory projections have been made with respect to the development of the oilseed area and production. The area allocated to cereals (and perhaps also oilseeds) under the continuation of Agenda 2000 could partly be set-aside area in case of decoupling. Results with respect to the development of fodder crops are only available in the study using CAPSIM, which analyses the impacts of implementing the MTR proposals. In this regard, however, silage area is projected to be reduced against Agenda 2000 levels because of the decline in beef production, greater incentives to shift towards a more extensive livestock production and other arable fodder.

5.3 Modelling Set Aside

Apart from area and beef payments, the set-aside obligation also contributes significantly to land use. Farmers in the EU are required to set a certain share of the Grandes Cultures area aside. However, the effective set-aside area does not necessarily correspond to the official rate. This can be due to some sort of slippage effect or to the fact that small producers are exempted from the set-aside requirement. Additionally, farmers are allowed to set aside land on a voluntary basis up to a maximum of 30 percent of their utilised area.

In ESIM, AGLINK, and in the FAPRI model effective set-aside area is calculated as the Grandes Cultures area multiplied by the set-aside rate and adjusted according to the share of small producers (for the FAPRI model, see Westhoff, 2004; for AGLINK, see von Lampe, 2004). In the ESIM and FAPRI models the set-aside area is further adjusted to include an observed slippage effect (Westhoff, 2004). In ESIM and AGLINK this amount of set-aside area is then subtracted from the total available area, before the sum of allocated area is scaled as described above (von Lampe, 2004)[28]. The possibility of setting land aside on a voluntary basis is not explicitly introduced in ESIM or in the FAPRI model. In case of the FAPRI model, however, the fact that total crop area is allowed to change as expected net returns change can potentially be explained by implicit movements in voluntary set aside. As returns increase (decrease), producers are enabled to increase (decrease) the total area allocated to production of cereals and oilseeds by assuming an implicit reduction (increase) in voluntary set aside (Westhoff, 2004). In AGLINK, the voluntary set-aside area is captured explicitly. It is modelled as a function of the obligatory set-aside rate and real returns for cereal and oilseed production. It is assumed that area, which is set aside on a voluntary basis, increases (decreases) when the obligatory rate decreases (increases) (von Lampe, 2004).

In CAPSIM, however, effective set-aside area is modelled differently. Effective set-aside area is a function of the Grandes Cultures area, the obligatory set-aside rate, a constant factor derived to reproduce the DG Agri forecast on the growth of set-aside, and a set-aside elasticity. The latter ought to capture the opposite change in voluntary set aside, which in AGLINK is assumed to accompany an increase in the obligatory set-aside rate (EUROSTAT,

[28] As mentioned above, in the FAPRI model the amount of land devoted to different activities is not scaled.

forthcoming). A similar approach has also been chosen for the PENN STATE TRADE MODEL. However, in contrast to the above models, no adjustment is made for voluntary set aside by small producers or the slippage effect (Stout, 2004). In WATSIM, the set-aside obligation is modelled as a reduction of yields by the percentage of the set-aside rate. As is case of the PENN STATE TRADE MODEL, no adjustment factors are included (Kuhn, 2004). Unfortunately it is not documented if and how the set aside issue is captured in the FAO WORLD FOOD MODEL.

In the GTAP model the set-aside requirement is modelled as a total factor productivity shock to land, which is allocated to Grandes Cultures (Kurzweil, 2004; Grinsted, 2004). As mentioned above, in the G-CUBED (Agriculture) model, policies affecting land use are not captured (McKibbin, 2004).

6 Summary and Outlook

This paper shows that certain structural elements are basically modelled quite similarly by the PE and GE models, while other features are treated differently. Crop supply, for example, is modelled as the product of yield and area in all PE models presented here. Differences only arise in the design of yield and area equations themselves. In this regard, specific characteristics of single models are the exogenous determination of yield in CAPSIM and parts of the FAO WORLD FOOD MODEL, the inclusion of lagged price, yield and/or area variables in WATSIM, in the PENN STATE TRADE MODEL, in the FAPRI model, and in the FAO WORLD FOOD MODEL as well as the use of partial adjustment factors in the PENN STATE TRADE MODEL. The coverage of permanent pasture area in ESIM is worth mentioning as well as the possibility that land can move into/out of production in the FAPRI model, the PENN STATE TRADE MODEL, and the FAO WORLD FOOD MODEL. An additional specific feature of the CAPSIM model is the inclusion of nonfood production on set-aside area.

In the GE models, the description of the model structure on the supply side is embedded in a generalised form of factor demand functions. Most GE models provide a nested structure, which describes the links between production and factor demand as well as final commodity demand. Total amount of land, which is allocated to the different agricultural activities, is fixed exogenously in the G-CUBED (Agriculture) and the GTAP model, while in general GE models assume full employment of total factor supply.With a fixed land price, however, GE models also could present fallow land endogenously.

Most of the selected agricultural sector models take land as a homogeneous factor. However, for these models heterogeneity of land can be addressed by assuming a continuum of land qualities. Another approach is used in CAPSIM, where a single price for land with fixed parameters reflecting different land qualities is specified. In GE models, restricted land mobility can be modelled, for example, by specifying migration functions that determine land flows between various considered sectors or by modelling transformation functions, which takes total land as an input and distributes it among various activities in response to relative rental rates. The latter approach is applied in the GTAP model, while the G-CUBED (Agriculture) model treats land as homogeneous.

To illustrate decoupling effects various and detailed relationships between the crop/fodder sector and the livestock sector have to be incorporated in the model structure. How feed prices affect livestock production varies in the selected models. In AGLINK, ESIM, the PENN STATE TRADE MODEL, the FAPRI model, and the FAO WORLD FOOD MODEL, feed demand is determined by own and cross feed prices and by the level of livestock production, with an implicit substitutability of feed components. The possibility of feed substitution is also given in CAPSIM and WATSIM. However, in contrast to the above models, CAPSIM captures feed demand as being based on a protein and energy balance. In WATSIM, demand for feedstuff relies only on an energy balance.

As ESIM and CAPSIM have extended their product coverage to fodder (silage maize, other fodder, and in ESIM, also grass) these models can illustrate decoupling effects in more detail than other models.

In the treatment of decoupled payments, a decoupling factor is used, or could be easily included in FAPRI, AGLINK, ESIM and WATSIM. This factor weights direct payments according to their assumed impact on production. CAPSIM and the GTAP model represent the new payments as a homogeneous land premium given to all agricultural land within each country. In the PENN STATE TRADE MODEL payments under the new CAP scheme are not yet captured as the old EU compensatory payments are considered to be neither completely coupled nor decoupled.

Set aside is captured quite differently among the selected models. Except for the G-CUBED (Agriculture) model, obligatory set aside is considered in almost every model[29]. The small producer regulation is included in AGLINK, ESIM and the FAPRI model, while ESIM and FAPRI also consider some slippage effect. Voluntary set-aside land is explicitly taken into account in AGLINK and CAPSIM. Regarding set aside, WATSIM, the PENN STATE TRADE MODEL and the GTAP model do not use any adjustment factors.

The studies that analyse the decoupling of CAP direct payments show that cereal area and production would decline under decoupled payments. Beef production would be significantly cut. Different and even contradictory results have been reached with respect to the development of the oilseed area and production. The area, which has been allocated to cereals (and perhaps also oilseeds) under Agenda 2000 regulations, could partly be set aside in the case of decoupling. Silage maize area is projected to be reduced against Agenda 2000 levels because of the decline in beef production and a shift towards a more extensive livestock production and other arable fodder.

The question of how far models are able to realistically simulate current policy reform heavily depends on structural links between the livestock and the crop/fodder sectors and on the way decoupled payments are included. Here, most models rely on parameters which have weak empirical foundations; especially the substitution elasticities in crop and fodder production, and feed demand between fodder and other feed products need further empirical analysis.

These aspects will have to be evaluated and addressed via further development of agricultural policy modelling. This is, of course, also true for the agricultural sector model ESIM. In

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[29] As mentioned above, information regarding the treatment of agricultural policies were not available for the FAO WORLD FOOD MODEL.

addition, ESIM is foreseen to be further extended and updated according to the framework of Workpackage 9 of the IDEMA project. This implies several steps.

Currently, ESIM covers the EU-15 as a single region. Because of significant differences in land use, farm structure, and implementation of the new CAP direct payment scheme, this highly aggregated region will be split up into smaller areas, most probably broken down to the national level. In addition, the model structure will be extended to include a land market module as well as the possibility that land is allowed to move into and out of production. Finally, a dynamic interface between ESIM and country-specific GE models has to be established. This interface will allow including macroeconomic variables, such as wages, rental rates and exchange rates. ESIM will provide data on the changes in support for agricultural commodities, which will enter the GE models (European Commission, 2003b).

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