Linkage of GTAP and DRAM for scenario assessment: methodology, application and some selected results

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1. Introduction

A model that is fully consistent on all levels of aggregation from micro to macro is not available and probably also not feasible. Looking at the agricultural sector, sector models give details about this sector, but there is no interaction between the agricultural sector and the rest of the economy. On the other hand, more macro-oriented models give too few details for agriculture, especially concerning supply response in the face of sometimes complex policy measures and specific agronomic features. As a result different type of models exists and if there is any overlap between the models they could produce different results for the same variables. To counteract this problem and to reach results that are more consistent with economic behavior at different levels of aggregation, different models can be linked.

The goal of this paper is twofold. First, it describes the technical issues connected with linking the Global Trade Analysis Project (GTAP) model and the Dutch Regionalized Agricultural Model (DRAM) in one consistent system of models. DRAM is a non-linear, partial equilibrium, positive mathematical programming model of the Dutch agricultural sector. It generates production volume for a number of crops and animal products as well as (among other outputs) manure at the regional level (Helming, 2005). GTAP is a standard comparative static multi-region Applied General Equilibrium (AGE) model of trade and production at the world level. In addition, both models are linked to the Land Use Scanner, which assesses spatial allocation of land for different uses. Since the Land Use Scanner uses a Geographic Information System (GIS), it enables the generation of spatially disaggregated results. Second, the paper assesses, using the developed model system, the economic consequences of two contrasting scenarios for food production and nature management in The Netherlands.

2. Modeling framework

The modeling framework used in this study was based on the GTAP model - the multi-region, multi-sector, computable general equilibrium model – which was used to access the world wide economic consequences of the scenarios (Section 2.1). The GTAP model was linked to the DRAM, which is Dutch regional agricultural sector model with environmental aspects. The focus of DRAM is on product- as well as and region-specific production technologies and on the production decisions of farmers (Section 2.2). In addition, both models are linked to the Land Use Scanner to endogenize the agricultural land availability via changes of the asymptote of the land supply curve (Section 2.3).

The models mentioned above are linked in such a way that in the projection generation process output of one of them becomes input for the other. The resulting model chain and its use in the prediction process are described in Section 2.4.

2.1. GTAP

The economic analysis was done with an extended version of the general equilibrium model of the GTAP model (Hertel, 1997). The standard version of GTAP was changed to model the specific features of agricultural sector not included in the standard model version. The extended version of the GTAP (see van Meijl et al. 2006) includes:

- The new land allocation method that takes into account the variation of substitutability between different types of land use. For this the OECDs Policy Evaluation Model (see: Huang et al. 2003 and OECD 2003) structure was used, as it is more detailed and distinguishes different types of land in a nested 3-level CET structure.
- The land supply curve that allows on endogenisation of the land supply. The land supply curve specifies the relation between land supply and a rental rate (Abler, 2003) and is described by the following equation:

  $$\text{Land supply} = a - b/\text{real land price} \qquad (1)$$

  where: “a” is an asymptote interpreted as the maximal potentially available agricultural land and b is a positive parameter determining the curve.
- Factor markets segmentation between agriculture and non-agriculture, which takes in account both wages and capital return differentials between these sectors. The segmented factor markets for labor and capital are incorporated in the standard GTAP model by specifying a CET structure that transforms agricultural labor (and capital) into non-agricultural labor (and capital) (Hertel and Keening, 2003). In order to have separate market clearing conditions for agriculture and non-agriculture, labor and capital markets were segmented in the model with a finite elasticity of transformation and the separate market prices for each type of labor and capital were introduced.
- Agricultural production quotas, which places a restriction on the volume of production. If such a supply restriction is binding, it implies that consumers will pay a higher price than they would pay in case of an unrestricted interplay of demand and supply. A wedge is created between the prices that consumers pay and the marginal cost for the producer. The difference between the consumer price and the marginal cost is known as the tax equivalent of the quota rent. This is implemented to the model by formulating the quota as a complementarity problem. This formulation allows for endogenous regime switches from a state when the output quota is binding to a state when the quota becomes non-binding. In addition, changes in the value of the quota rent are endogenously determined.

2.2. DRAM

DRAM can be defined as a comparative static, partial equilibrium, mathematical programming, regionalized model of the Dutch agricultural sector with environmental aspects. It generates production volume for a number of crops and animal products as well as (among other outputs) manure at the regional level (Helming, 2005). DRAM distinguishes 14 regions on the basis of agricultural potential.

The focus of DRAM is on regional and national agricultural production and the interactions between agricultural activities in terms of agricultural input and output markets. DRAM concentrates on the effects of policy changes on input allocation and prices. The core of DRAM is an optimization block that maximizes total profits from agriculture with the restriction that economic, technical, environmental, spatial and policy constraints are respected. Here, profits are defined as revenue minus total variable costs. The basic underlying assumption is that farmers' behavior can be described by the maximization of profits from individual agricultural activities. Profits are maximized simultaneously across all farms to take into account the relationship between market effects and farmers' behavior. Simultaneous optimization of farm profits assumes an optimal allocation of agricultural inputs and outputs across the farms, so that profits from agriculture at the national level are maximized. This optimal allocation of inputs and outputs is achieved when marginal costs are greater than or equal to marginal revenues for all agricultural activities in the model.

Prices of outputs and purchased variable inputs are treated as exogenous variables, as they are assumed to be determined at the internal EU market or world market. Fixed inputs in the model are land and quotas.

2.3. Land Use Scanner

The Land Use Scanner is a land-use simulation model developed for the Netherlands (Hilferink and Rietveld, 1999). The Land Use Scanner combines land claims with spatial data on existing land use, land suitability and policies into a forecast for future land use. This forecast is in cells of 500 x 500 meters. Land claims per land-use class are exogenous to the model.

The land allocation in cells is grounded in economic theory. The fundamental hypothesis is that land use is determined by the suitability of land for a particular purpose. Different land-use categories are pictured as actors competing for limited space, with each area of land going to the category that can derive the largest benefits from it – an approach based on the bid-rent theory for urban land use (Alonso 1964) and on von Thünen’s theory of agricultural land use (von Thünen, 1875). This theory leads to a logit-type land allocation equation. Two constraints are added to this equation: one to ensure that the total area of land allocated to land use j is equal to the total amount needed; that amount (the claim) is derived exogenously. The second constraint ensures that the total amount of land allocated to all uses is equal to the amount available.

2.4. Model chain in the projection process

Figure 1 shows the models use in the prediction process. The models’ chain starts from the Land Use Scanner, which calculates the land-use projections being a consequence of expected economic developments and of government policies on the use of space and other scenario assumptions. The land-use projections from the Land Use Scanner are fed into GTAP, which assess the consequences of the scenarios for the Netherlands as a part of the world economy. The land use projections from Land Use Scanner are used to alter the asymptote of the land supply curve in GTAP. The output of the GTAP model includes real product prices and sectoral productivity changes. They, in turn, are used in DRAM, which generates production volume for a number of crops and animal products as well as (among other outputs) manure at the regional level.

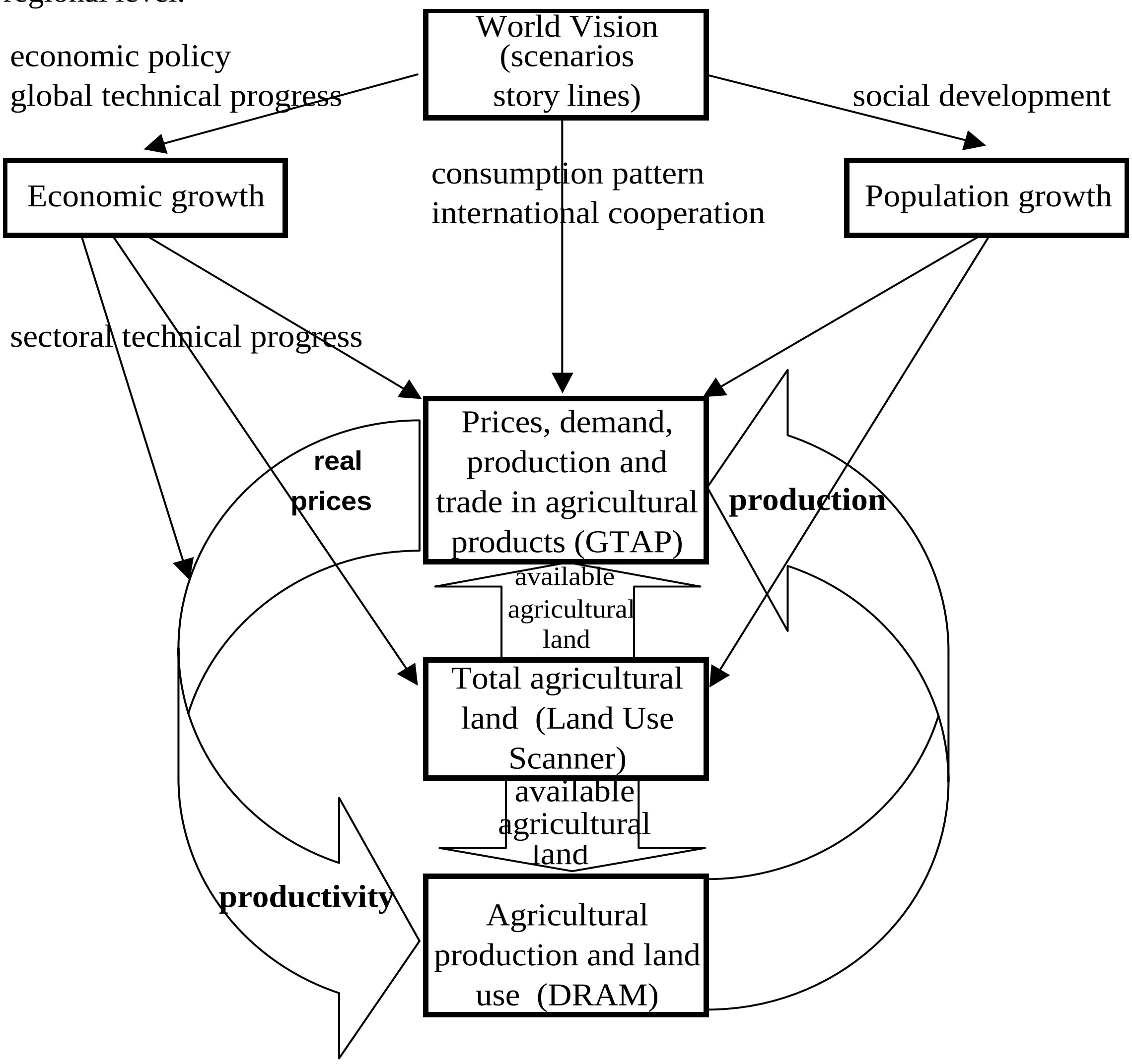

Figure 1: The modeling framework of Land Use Scanner, the GTAP model and DRAM

Since both the GTAP and DRAM models predict the production changes of agricultural sectors, the iterative solving procedure of both models leading to the consistent production results is necessary. The DRAM and the GTAP model production changes can differ. These differences are the result of differences in the cost structures in DRAM and the GTAP model caused, e.g., by manure policy and different product and region specific production technologies taken in to account in DRAM but not present in the GTAP model. The tax or subsidy equivalents of these costs will be calculated to fix the sectoral production in the GTAP model on the level obtained by DRAM. This in turn will produce new real product prices and productivity changes, which will be used for DRAM simulations to calculate the new output changes. The iteration process stops when the agricultural production changes in DRAM will be sufficiently close in the two consecutive iterations.

Below it is discussed how consistency between DRAM and GTAP is achieved.

3. Making DRAM consistent with GTAP: approach use

According to Jensen et al. (2002) linking different models to analyze specific scenarios require coordination in at least two respects:

- consistency in behavioral description in the involved models;
- consistency in the definition of the scenarios analyzed.

Consistency in the models' behavioral descriptions assumes that reactions of the models to exogenous shocks are consistent. This requires that underlying functional specifications and behavioral parameters are the same in the involved models. This means for example that elasticity of substitution between different inputs in production or different commodities in consumption are identical across models. In the case of DRAM and GTAP, the behavior of the two models can be quite different. GTAP is a multi-country general equilibrium model focusing on trade and substitution between fixed resources in production and substitution in consumption. DRAM is a partial equilibrium model focusing on regional supply of key agricultural outputs, taking into account substitution in production through joint use of land and manure application room. Moreover, differences in behavior can be expected because of differences in specification of variables, differences in data sources and differences in base year. Among others these differences explain the differences in cost shares, as described in paragraph 3.1.

Consistency in the definition of scenarios requires that the set of variables exogenous to both models are the same. A complication to that requirement is the fact that some variables may be exogenous in one model but endogenous to another model. For example, manure markets are endogenous in DRAM but they not included in GTAP. In this case an iterative procedure is necessary to ensure consistency between manure prices in DRAM and output prices in GTAP.

3.1. Costs shares of different costs components in DRAM and GTAP

This section analyses the differences in costs shares of different cost components in DRAM and GTAP. Table 1 and 2 show the costs shares of feed, other intermediates, internal deliveries, land and other fixed inputs (capital plus labor) in total costs in the base in GTAP and DRAM respectively. Tables 1 and 2 show that in the grain sector costs shares of capital and labor in GTAP exceeds the comparable costs shares in DRAM. This is partly explained by the base difference in the data bases of both models. The GTAP model uses 2001 but DRAM uses 1996 data, which are only partly updated to 2002 data. Nevertheless it is surprising that the costs shares of capital and labor in the grain sector exceed the costs shares of capital and labor in the sugar sector in GTAP. This is maybe explained by the fact that table 1 uses data from the GTAP database for only one year and this could be a relative good year for cereals. A solution to this would be to use average results over a certain time period.

The cost structure in the horticultural sector in DRAM and GTAP are relatively comparable. Costs of seed and other internal deliveries in the crops sector are included as intermediates in DRAM. Here again costs shares of capital and labor in GTAP exceeds comparable costs shares in DRAM. This is maybe explained by the high prices of consumption potatoes in 2001. The livestock sectors also show relatively large differences in costs shares between DRAM and GTAP. Especially the costs share of labor and capital in the cattle sector in GTAP exceeds the corresponding costs share of labor and capital in DRAM by far.

Table 1: Shares of different cost components per sector in GTAP in base (2001) (index)

	Wheat	sugar beets	horticul-ture	crops	cattle	pig and poultry	milk
Other intermediates	0,46	0,58	0,35	0,33	0,28	0,25	0,27
Feed	0,00	0,00	0,00	0,00	0,18	0,41	0,19
Internal deliveries	0,01	0,00	0,04	0,14	0,14	0,18	0,03
Capital plus labor	0,47	0,37	0,54	0,47	0,35	0,14	0,45
Land	0,06	0,05	0,07	0,06	0,04	0,02	0,06
Total	1,00	1,00	1,00	1,00	1,00	1,00	1,00

Source: GTAP database 6.4

Table 2: Shares of different cost components per sector in DRAM in base (2002) (index)

	wheat	sugar beets	horticul-ture	crops	cattle	pig and poultry	milk
Other intermediates	0,53	0,43	0,40	0,64	0,14	0,15	0,28
Feed					0,34	0,39	0,12
Internal deliveries					0,31	0,26	0,12
Capital plus labor	0,38	0,52	0,58	0,33	0,21	0,19	0,46
Land	0,08	0,04	0,01	0,04			0,02
Total	1,00	1,00	1,00	1,00	1,00	1,00	1,00

Source: DRAM database

3.2. Calibration of DRAM parameters using GTAP results

DRAM includes flexible functional forms to model supply and demand of agricultural outputs. To make the behavior of DRAM and GTAP consistent as much as possible, we calibrate the parameters of DRAM equations using price and quantity pairs and demand elasticities derived from GTAP.

To achieve consistency between GTAP and DRAM for a given scenario, changes of sectoral output prices, sectoral productivity and activity levels from GTAP are used to calibrate the parameters of the activity specific inverse supply equations in DRAM.

Prices changes of outputs per sector from GTAP can be directly linked to final output prices changes in DRAM from the linkage of sectors and activities as described in the Appendix 1). Price changes of roughage and young animals are not available from GTAP therefore related changes in final outputs are used (e.g. prices of piglets in DRAM are related to prices of outputs from sector pig and poultry sector in GTAP).

Yield changes per hectare in the arable and horticulture sectors are linked to corresponding activities in DRAM. GTAP does not include animals as an input category. Therefore, productivity changes per animal (e.g. meat per pig, milk production per dairy cow) in DRAM are derived from figures found in the literature. GTAP also delivers changes in milk production per hectare. Together with changes in milk production per dairy cow, changes in number of dairy cows per hectare per technology in DRAM are calculated.

Production is endogenous in DRAM. Besides scenario specific changes in input and output prices and productivity, changes in land allocated to crop sectors from GTAP are used to re-calibrate the parameters of the inverse supply equations, such that consistency between prices and quantities between GTAP and DRAM is reached (see Appendix 2). For the animal activities the procedure is slightly different. From GTAP the change in output of the livestock sectors is known. Using the exogenous change in animal productivity, mentioned above, we can calculate the change in the number of animals.

Results from GTAP, are also used to calculate scenario specific price elasticities of demand per sector. Together with the corresponding price and quantity pairs, these elasticities are used to calibrate the parameters of output and activity specific total inverse linear demand functions for final agricultural outputs and export demand functions for roughage and young animals. The problem is that price elasticity of demand is an endogenous variable in GTAP. This means that price elasticities of demand have to be re-calculated in each iteration until convergence is reached, that is price and quantity changes per period are constant in every following iteration.

3.3. Iterative procedure

Even when DRAM parameters are calibrated using GTAP data, production changes calculated from DRAM can be (and mostly are) different than these produced by GTAP. The most important reason of this is the inclusion of manure markets in DRAM. These markets are not modeled in GTAP. As the result, consistency between production changes in GTAP and DRAM, can only be reached by applying an iterative procedure.

Graphically the iterative procedure is presented below. Given a certain scenario assumptions, GTAP is solved first. Then prices and quantities taken from GTAP are translated to corresponding DRAM variables and are used to calibrate the parameters of the supply and demand functions in DRAM (see appendix 2). Next, DRAM is solved. Results differ from GTAP results because of the inclusion of manure markets in DRAM and other differences e.g. differences in costs shares. In the next iteration, changes in output from DRAM are used as exogenous output changes in GTAP. The GTAP is solved and corresponding GTAP changes in prices and elasticities are used as input in DRAM. This iterative procedure continues until consistency is reached, that is in every following iteration price and quantity changes per scenario are constant. To illustrate how results from GTAP are used in DRAM, DRAM results of iteration 0 are discussed in Appendix 3 of this paper.

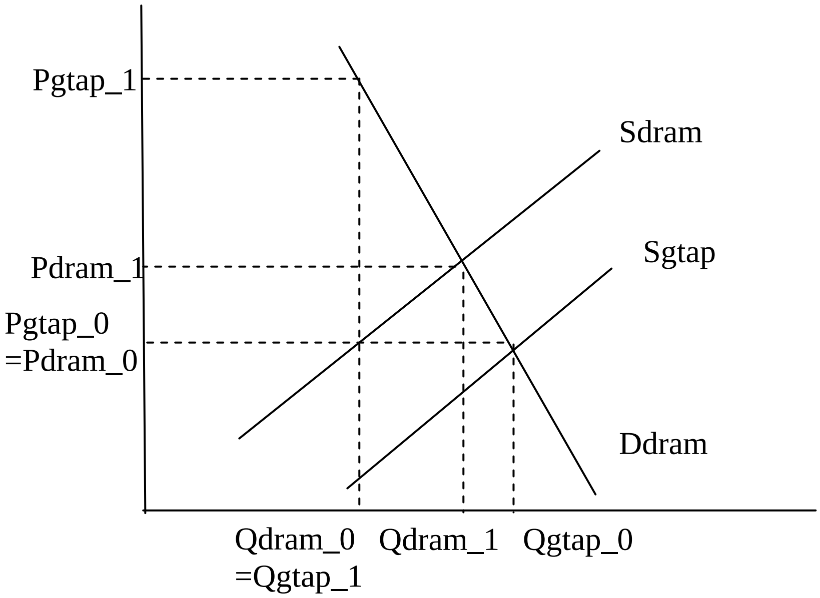

Figure 2: Graphical presentation of the iterative procedure between GTAP and DRAM after two iterations.

Graphically the approach to converge supply and demand in DRAM and in GTAP is presented in Figure 2. The variables in Figure 2 are defined as follows:

Qgtap_0	=	output from GTAP in iteration 0
Qdram_0	=	output from DRAM in iteration 0
Qgtap_1	=	output from GTAP in iteration 1 (equal to output from DRAM in iteration 0)
Qdram_1	=	output from DRAM in iteration 1
Pgtap_0	=	market price from GTAP in iteration 0
Pdram_0	=	market price from DRAM in iteration 0 (equal to market price from GTAP in iteration 0)
Pgtap_1	=	market price from GTAP in iteration 1
Pdram_1	=	market price from DRAM in iteration 1
Ddram	=	inverse demand function used in DRAM and derived from GTAP
Sdram	=	inverse supply function in DRAM
Sgtap	=	inverse supply function in GTAP

4. Scenario assessment

4.1. Scenario assumptions

To put the model chain to work, we use it to assess the economic consequences of two contrasting scenarios for food production and nature management in The Netherlands. Scenarios developed in EURURALIS project were used (see Klijn et al. 2005). From the four scenarios presented in the EURURALIS project, two extreme scenarios were chosen:

- The Global Economy (GE) scenario, which is the most liberal and free market scenario. It assumes the WTO negotiations are successful, global trade fully liberalized and a further eastwards EU enlargement including Turkey. Technological change is high. Poor countries will catch-up and experience high economic growth. This scenario shows the highest income growth for almost all regions (see Figure 3). Technological change is driven by economic profit and not directed to or hampered by environmental (planet) or social (people) considerations. Genetically modified crops are accepted and there are few environmental concerns.

- The Regional Communities (RC) scenario, which is the most regulated and regionally oriented scenario. In this scenario both economic and non-economic values are important while regional or national interests prevail. Trade and agricultural policies remain almost unchanged, except for export subsidies that are abolished because this kind of "dumping" is politically unacceptable. EU integration is only partial and technological change is limited because of segmented markets and the focus on non-economic issues (GMOs are not allowed, environment is important). The resulting economic growth in the RC is lower than in the GE scenario. Social values lead to catching up of developing countries because they can adopt existing technologies from developed countries.

The scenario results are calculated through recursive updating of the database for three consecutive time periods, 2001 – 2010, 2010 – 2020 and 2020 – 2030 such that exogenous GDP targets are met given exogenous estimates on factor endowments - skilled labor, unskilled labor, capital and natural resources- and population. Therefore, scenario assumptions are made for each of these periods separately. The quantification of scenario assumptions was done in the EURURALIS project framework[1].

The constructed modeling system was used to quantify and analyze the long-term consequences of the scenarios for food production and nature management for The Netherlands as a part of the world economy. They lead to two contrasting development paths of the agricultural sector and therefore form the confidence interval for future projections of the agricultural sector development.

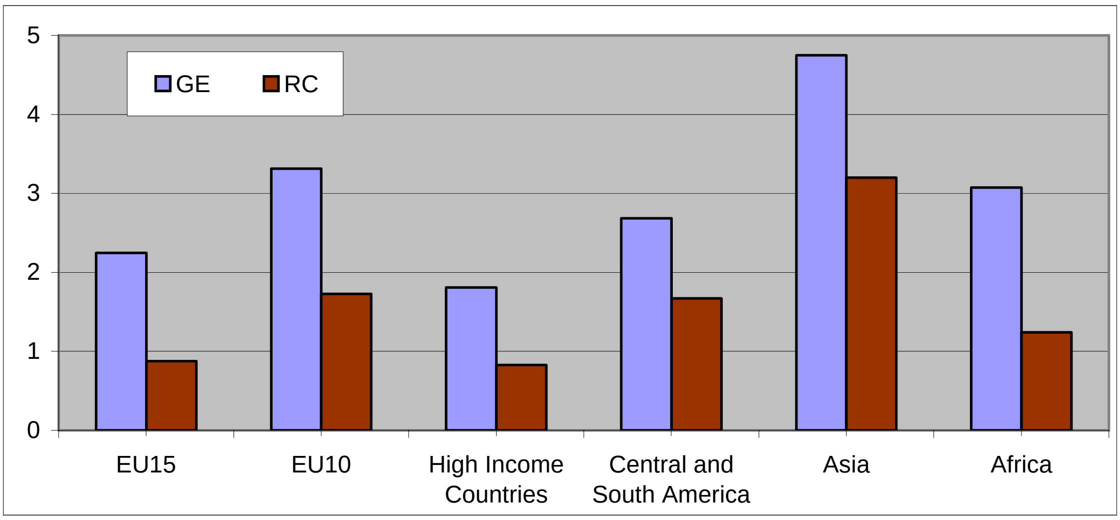

Figure 3: Assumed GDP growth per capita for different groups of countries yearly growth rates in 2001 - 2030

[1] The exact numbers are available from the authors on request.

Following the scenario storylines, we implemented the specific trade liberalization, agricultural policies and consumer preferences (see, Table 3).

Table 3: Policies and consumer preferences in the scenarios

	Both scenarios	Global Economy	Regional Communities
Border support			
Export subsidies	2003 CAP reform	Abolished	Abolished
Import tariffs	2003 CAP reform	Abolished	No change
Trade blocks	Enlargement to EU25	Turkey, Rumania, Bulgaria, FSU accede EU	Manufacturing: FTAA (North + South America), TUR-Middle East and North Africa, Rest Africa, FSU
Border support			
Domestic subsidies	2003 CAP reform (incl. decoupling)	Abolished	+10%, linked to env. and social targets
Quotas			
Milk and sugar quota	2003 CAP reform	Abolished	Self sufficient EU
Consumer preferences			
Preference for regional products		No	Preference for products from own region (5%)
Preference for protein from meat		Endogenous outcome	Meat consumption 10% lower

4.2. Scenario implementation and data

The land claims for Land Use Scanner, were generated from the estimated double-log relationship between land claims and real GDP and population. The dummy variables were introduces to the equations to explain structural changes in the pattern of the estimated relationships. Such a dummy explains decrease of the agricultural land due to the MacSharry reform or government policy towards nature.

The solving procedure of GTAP assumes that exogenous GDP targets are met given exogenous estimates on factor endowments - skilled labor, unskilled labor, capital and natural resources - and population. This implies that at the overall country level technological change is endogenously determined within the model (see also Hertel *et al.* 1999), however, the relative sectoral technological changes are exogenously assumed (as in the CPB, 2003). In line with CPB approach (CPB, 2003), it was also assumed that all inputs achieve the same level of technical progress within a sector (i.e. Hicks neutral technical change).

The approach used in our research deviates from this assumption by using additional information on yields from FAO. For the land-using sectors yields are exogenous and obtained in the base run from scenario specific assumptions based on deviations of the FAO yield projections (FAO, 2003). In The Netherlands, they are altered in the second step to obtain the total agricultural land use changes consistent with the agricultural land availability obtained from the Land Use Scanner and sectoral growth rates of production calculated from the DRAM. For the non-land using sectors, Hicks neutral technical change is assumed.

Version 6.4 of the GTAP model database for simulation experiments was used. The GTAP database was aggregated to 18 sectors and 37 regions (see Annex 4). The sectoral aggregation distinguishes agricultural sectors that use land and sectors engaged in the Common Agricultural Policy (CAP). The regional aggregation includes all EU 15 countries (with Belgium and Luxembourg as one region) and all EU 10 countries (with Baltic regions aggregated to one region and with Malta and Cyprus included as one region) and the most important countries and regions outside EU.

The most important data sources for DRAM are the Dutch Farm Accountancy Data Network (FADN), the Agricultural Census of Statistics Netherlands (CBS) and the Dutch Agricultural Input Output Table (AIOT). The FADN includes about 1500 farms every year and is a stratified sample of all farms in the Netherlands. The sample contains very detailed information about costs and revenues of individual farms. In order to be used in DRAM and the AIOT, technical/economic data from FADN are translated from farm level into activity level. Agricultural input use and production per activity are multiplied with regional activity levels taken from the Agricultural Census to determine total regional agricultural input use and production. The costs and revenues calculated by DRAM are harmonized with corresponding transactions found in the Dutch AIOT. Other important data sources for technical/economic information at the activity level are IKC-V (1993), Praktijkonderzoek Veehouderij (2001), IKC-agv (1995) and Praktijkonderzoek Plant & Omgeving B.V. (2001), and Statistics Netherlands for information about manure and nutrients excretions per animal per year.

5. Simulation results GTAP and Land Use Scanner

The scenario results show a huge increase in agricultural land area in the developing countries. Macroeconomic factors such as the GDP and population growth are the main factors driving this increase (Figure 4). In the developing countries such an expansion of agricultural land is possible since a lot of idle land, which could be converted to agricultural land, is available in these countries. In these regions agricultural land can still be expanded between 35% and 75% without leading to a high increase in the rental rate for land.

The macroeconomic factors influence the agricultural land changes in two different directions. The GDP and population growth drive demand for food products and so for the agricultural land. On the other hand the economic and population growth creates demand for industrial land and housing and stimulates outflow of land from agriculture. The outflow of land from agriculture is facilitated by the yield growth.

For the EU countries the negative impact of the agricultural land conversion to non-agricultural land and yield growth on agricultural land area compensates for and even prevails over (in the case of the new EU members) the positive impact generated by growing demand for food (Figure 4).

In the case of the highly developed counties, the reduction of domestic support has an important negative impact on agricultural land. As the result, a significant but not massive reduction of the total agricultural area in EU-countries is predicted. The relatively lower outflow of land from agriculture to non-agricultural uses and higher level of support in the RC scenario compared with GE scenario causes an agricultural land decrease of 3,5% less in RC than in GE scenario in 2001-2030 (Figure 4).

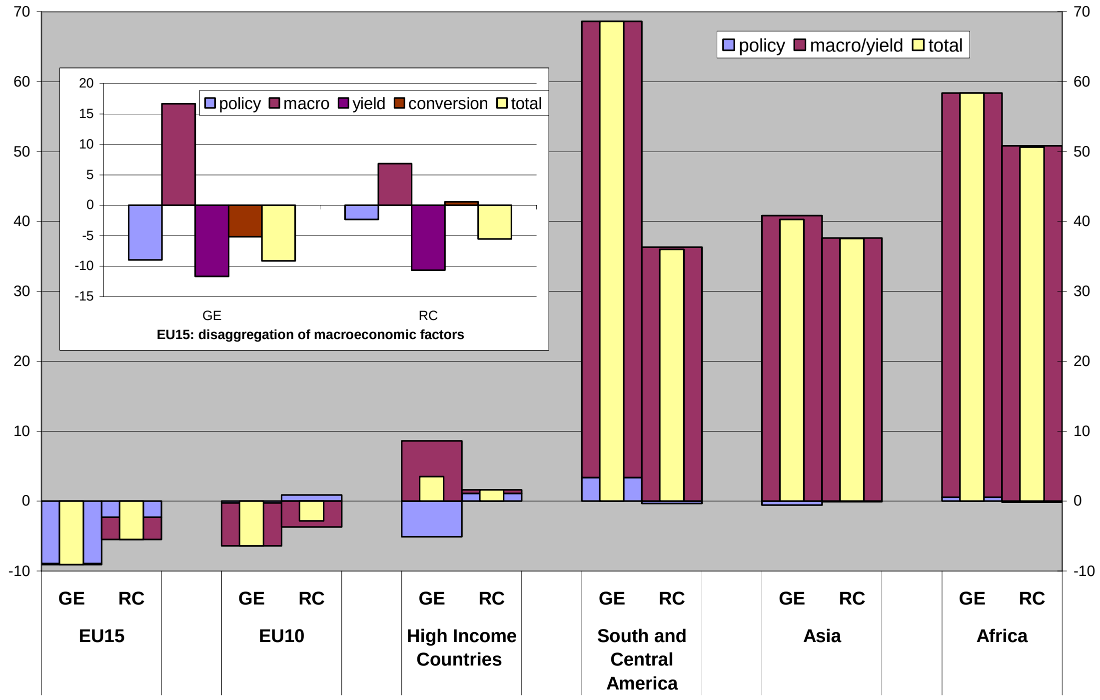

Figure 4: Total agricultural land growth in 2001-2030: the macro-economic and policy impacts

In The Netherlands the agricultural land area is decreasing in the whole simulation period and is up to 10% lower in 2030 than in 2001 for both EU15 and The Netherlands (Figure 5). The three major forces which drive this process are decoupling and reduction of direct payments, conversion of agricultural land to land utilized for non-agricultural purposes and yield growth. The increase of demand for food caused by GDP and population growth tempers the influence of these factors

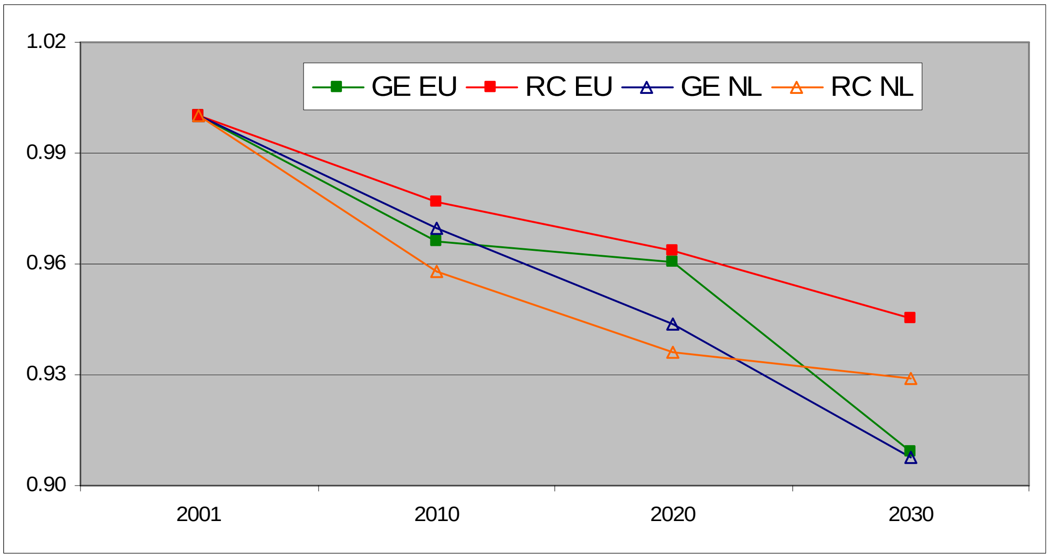

Figure 5. Agricultural land in EU15 and the Netherlands in GE and RC scenarios: 2001=1.

In general, the reduction of payments in the GE scenario causes a faster decrease of the agricultural land area in the GE scenario than in RC scenario when payments are not reduced and even increase in the last simulation period. Due to the additional conversion of agricultural land to land use for nature assumed for The Netherlands, the agricultural land area decreases faster in the Netherlands than in EU15. This conversion process is especially fast in the 2001 - 2010, which causes faster decrease of the agricultural land area in The Netherlands in the RC scenario than in GE scenario at the beginning of the simulation period.

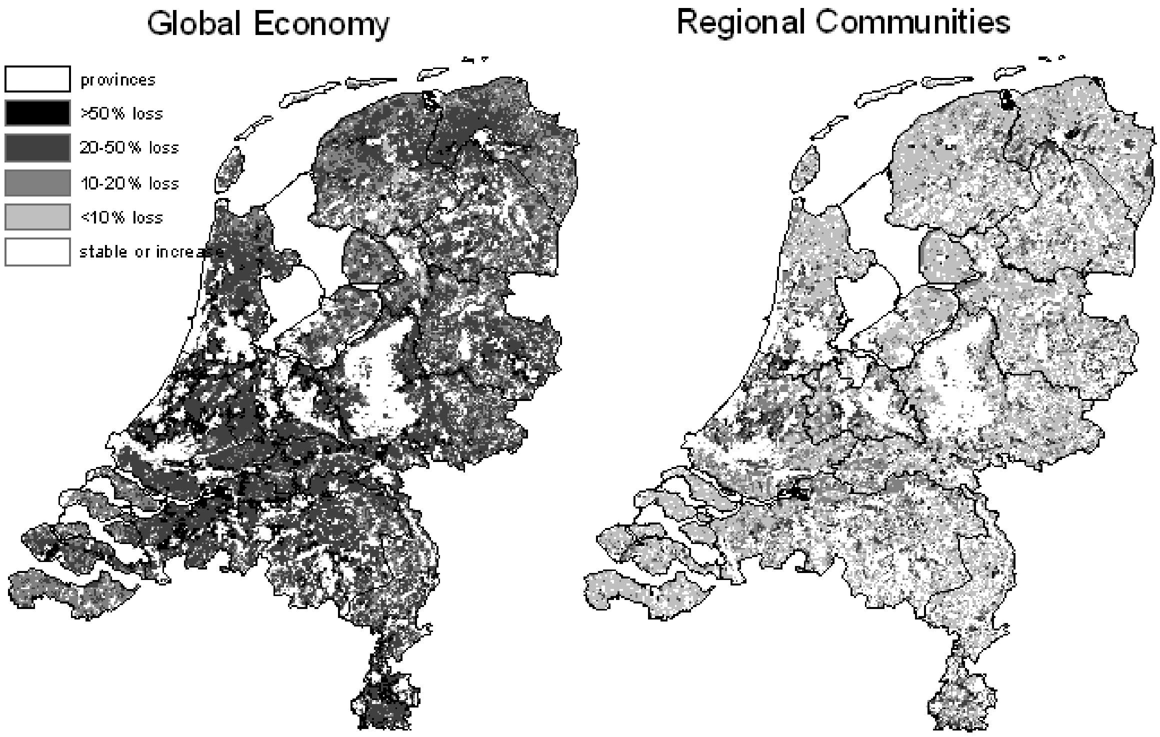

Figure 6. Changes in agricultural area

The extent of decrease of agricultural area differs significantly per region in The Netherlands. Figure 6 shows the percentage of land lost to (or gained by) agriculture per cell, as a proportion of the total area per cell. We see that the agricultural sector has to give up land mostly near the larger cities and along axes of infrastructure; this is the case in both scenarios, but under Regional Communities the loss is lower and less concentrated. Notably, there is more loss around the main northern city of Groningen than under the Global Economy scenario. There is also some increase of agricultural land under both scenarios, mostly in or near nature zones – and rather unrealistically also in large cities. This is an aspect of the model that will still need working on, although the changes are small: typically, the model allocates a few percentage points of land per cell to agriculture in these zones. The increase of agricultural land is higher under the Global Economy scenario, where because of its higher bid price it is able to outcompete nature in some areas, notably the Veluwe, which is the largest forest area in the country. There and in the coastal dunes, in some cells up to 40% of the land changes from nature to agriculture. These are, one must assume, farmers pushed out of other areas as a result of urbanization.

6. Convergence of the iteration procedure between the GTAP and DRAM models and impact of DRAM on the GTAP model results

As states in Section 3, in order to obtain consistency between the GTAP model and DRAM production growth rates an iterative projection procedure was used. The two-step iterative procedure works as follows:

1. Using DRAM sectoral production growth projections, the GTAP model generates projections of real product prices and sectoral productivity changes.
2. The DRAM uses the GTAP model projections of prices and sectoral productivity changes to generate projections of the sectoral production changes.

The iterative procedure starts with iteration 0 in which the GTAP model calculated the sectoral output changes itself. These data are used for DRAM calibration.

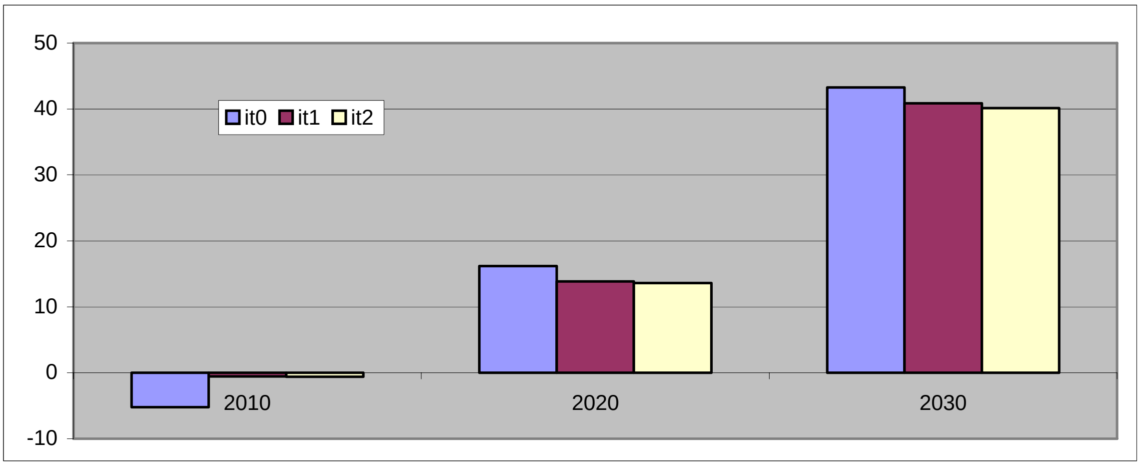

Figure 7. Pig and poultry real price changes in 2010 – 2030 in three consecutive iterations in the GE scenario.

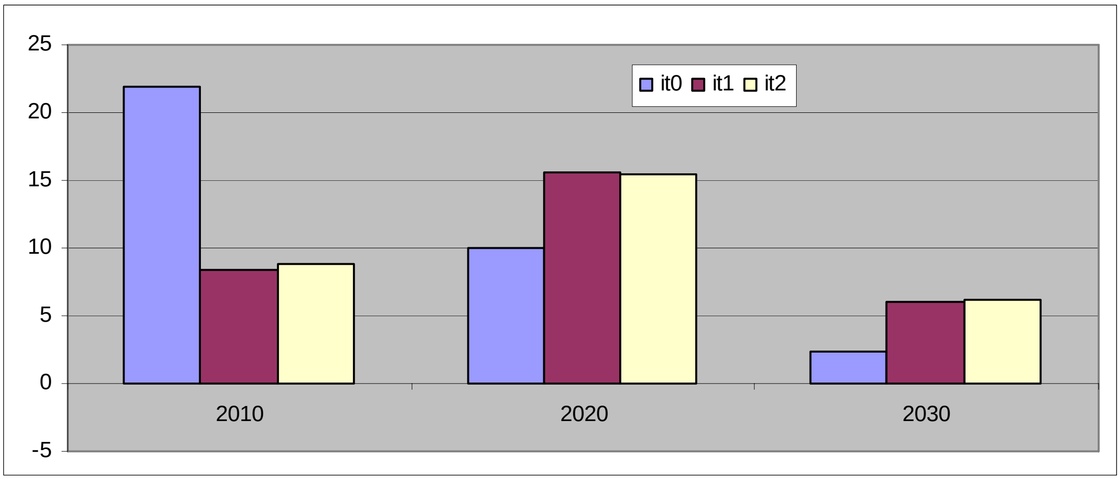

Figure 8. Pig and poultry output changes in 2010 – 2030 in three consecutive iterations in the GE scenario.

This iterative procedure stops when projections of the sectoral production changes are sufficiently close in the two consecutive iterations. Since the main factors driving production in DRAM are prices, the convergence of the procedure requires the convergence of real product prices in the GTAP model as well.

For most sectors the procedure converges quickly, as for example in the pig and poultry sector (Figure 7 and 8).

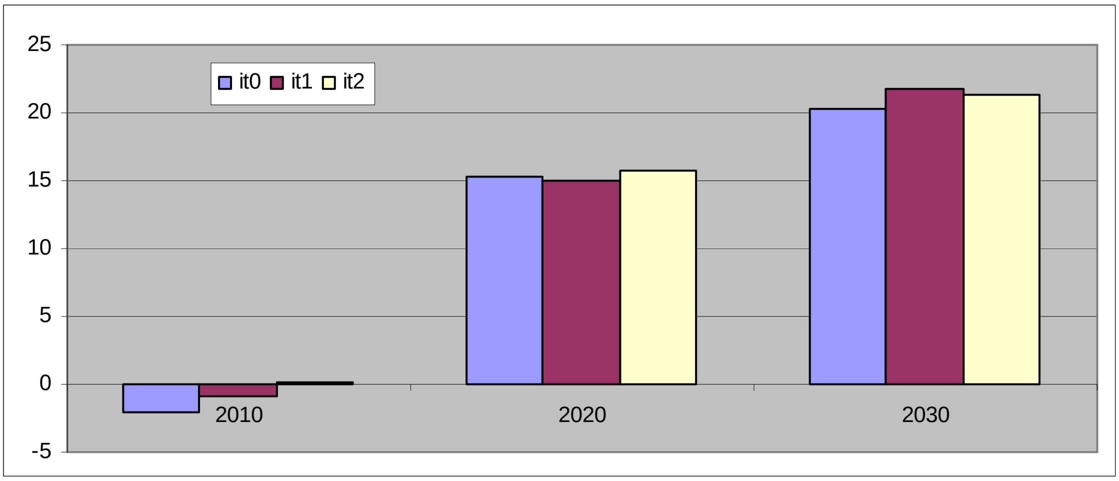

Figure 9. Wheat real price changes in 2010 – 2030 in three consecutive iterations in the GE scenario.

However, in spite of convergence of real wheat prices (Figure 9), wheat production does not converge (Figure 10). The small price changes of wheat lead to big changes of wheat production in the DRAM. The reason for this is that DRAM does not include the price change but the elasticities of cereals demand as derived from the GTAP results. These can be quite different in the different iterations. This should be improved upon in the future.

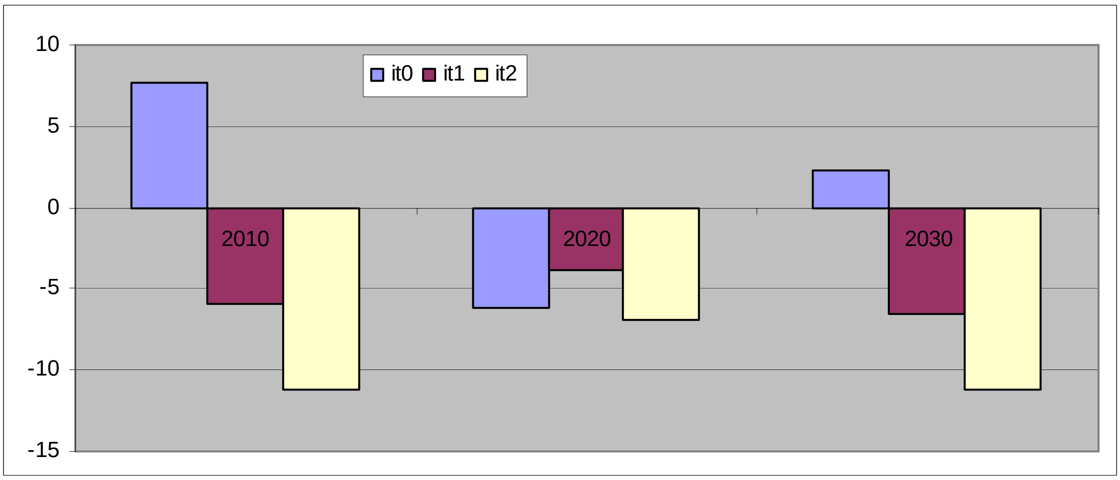

Figure 10: Wheat output changes in 2010 – 2030 in three consecutive iterations in the GE scenario.

According to our simulation results, generated by DRAM output changes have a significant impact on output development in the GTAP model. However in most cases the GTAP model and the DRAM predict the same direction of changes (Figure 11). On the contrary, DRAM output changes implemented in the GTAP model have a rather small impact on the GTAP model real price changes except for the cattle sector. This, together with the close connection between cattle and wheat in DRAM, is probably one more reason why there is no convergence of wheat production growth rates (Figure 12).

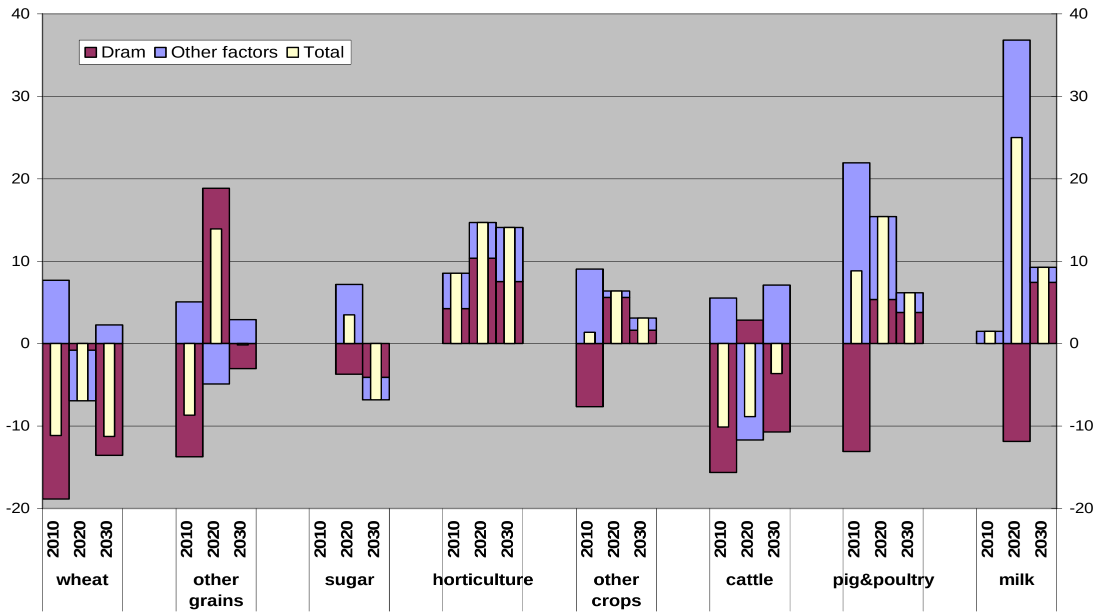

Figure 11: Impact of DRAM on production growth in GE scenario in 2001 - 2030.

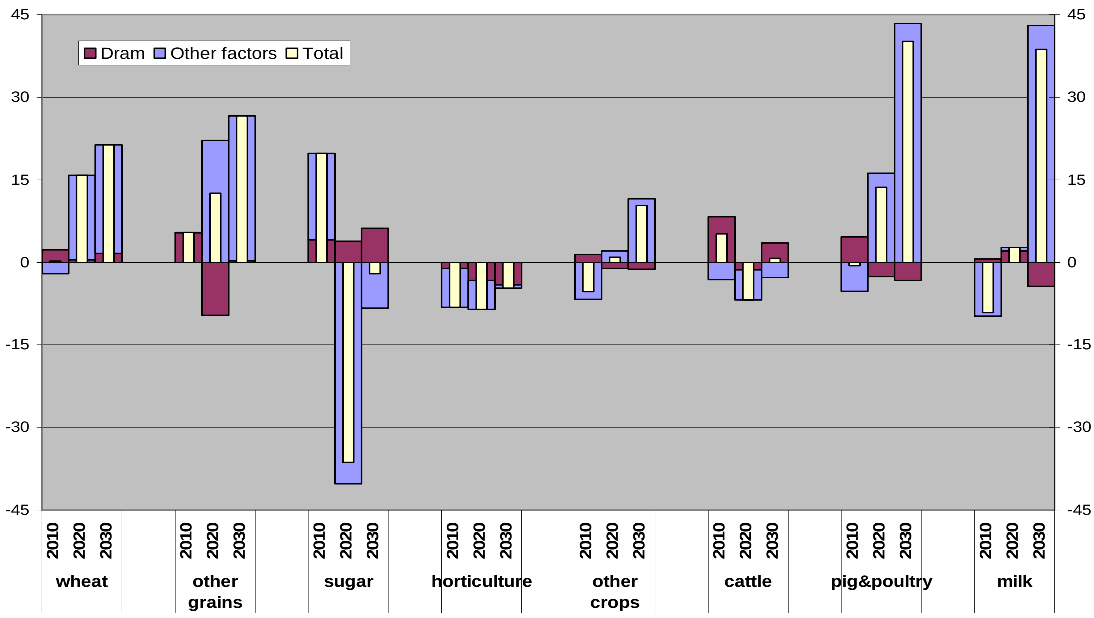

Figure 12: Impact of DRAM on real price growth in GE scenario in 2001 – 2030.

7. Some selected scenario results for the Netherlands derived from DRAM-GTAP modeling tool

Figure 13 shows that the acreage of land allocated to arable crops decreases sharply under the two scenarios as compared to the base in 2002. This is especially explained by a decrease in the acreage of cereal crops[2]. Under GE land allocated to cereals will

[2] The decrease of the cereal crops is mainly explained by the interplay between cereals and grassland through the regional land balances. Demand elasticities derived from GTAP results are used to calibrate parameters of the linear inverse demand equations in DRAM. It is found that especially under

be 50% below the base in 2030. Under RC this percentage equals about 40%. Both scenarios show an increase in the share of high nutrients input crops (consumption potatoes, sugar beets) relative to low nutrients input crops (cereals).

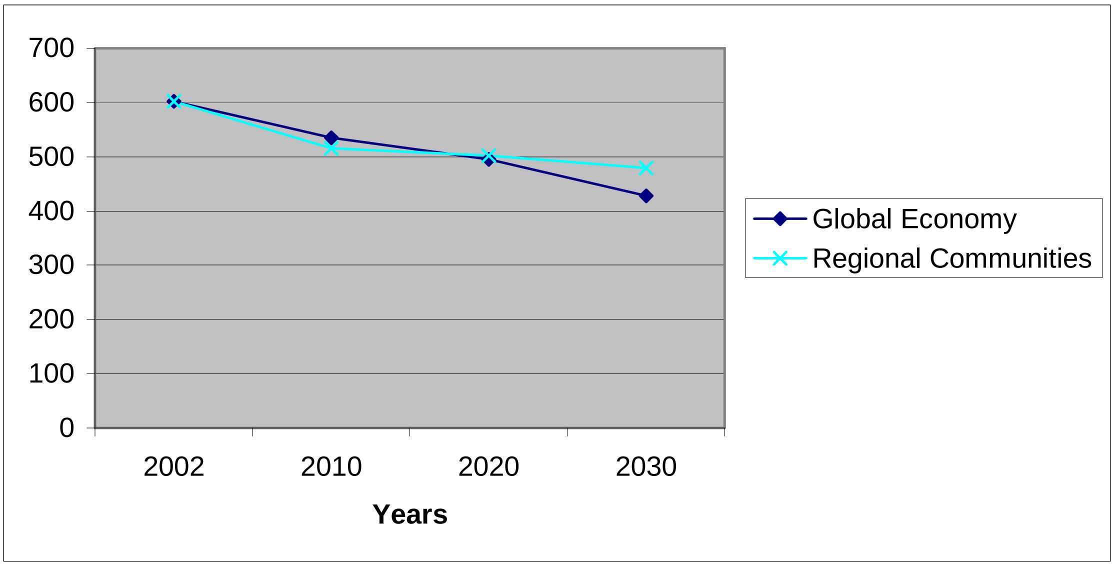

Figure 13: Development of the acreage of total arable crops (1000 ha) over the two scenario's (2002-2030).

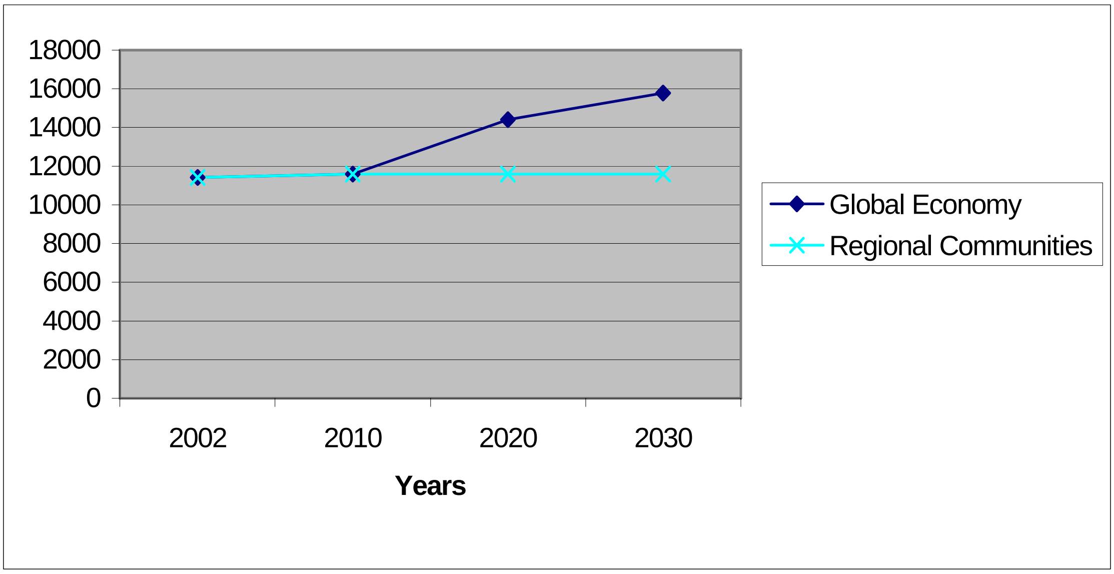

Figure 14: Development of total milk production (1000 ton) over the two scenario's (2002-2030)

Figure 14 shows the change in total milk production under the different scenarios. Under RC the increase in milk production in the Netherlands is limited to the increase in the milk quota by 1.5%. Under GE the abolition of the milk quota system results into an increase in total milk production in the Netherlands of about

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the GE scenario absolute values of demand elasticities for roughage crops are low compared to corresponding values for cereals.

40%. Further increase in milk production in the Netherlands is restricted by manure policies and increased costs of capital, land and labor.

Figure 15 shows the development of the share of grassland with high nitrogen input per hectare in total grassland acreage under the different scenarios. Under GE the trend is increasing whereas under RC this trend is decreasing. The explanation of this is a rather technical one. From the data it can be shown that milk production per hectare grassland increases with nitrogen input per hectare grassland. This means that grassland activities with high nitrogen input per hectare go together with a relatively high input of milk quota and a relatively low input of land. The decreasing trend under the RC scenario, mentioned above is explained by increasing shadow price of milk quota, relative to the shadow price of land. Under GE this is the other way around as milk quota are abolished and the shadow price of milk quota decreases to zero.

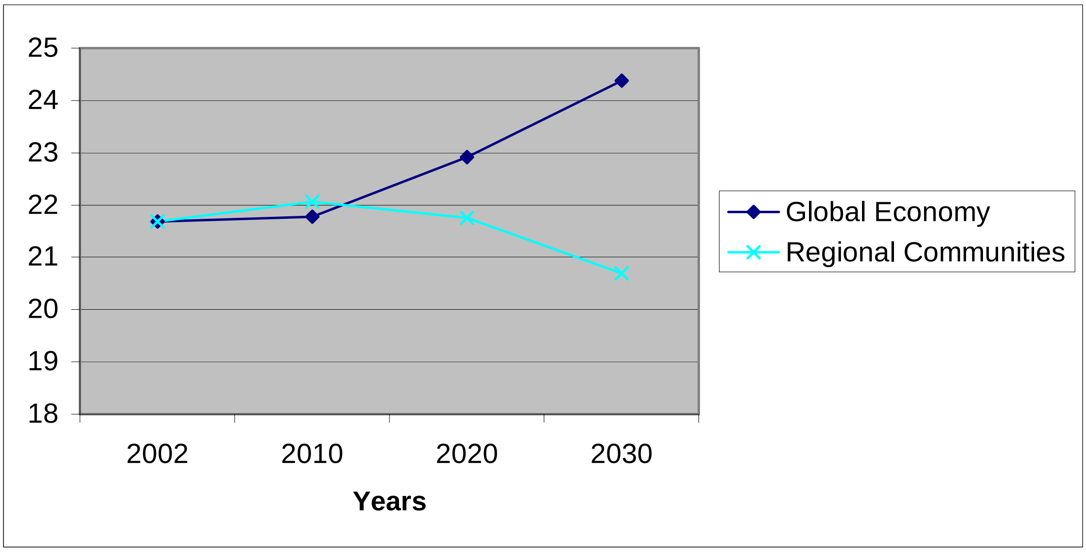

Figure 15: Development of the share of grassland with high nitrogen input per hectare in total grassland acreage over the two scenario's (2002-2030).

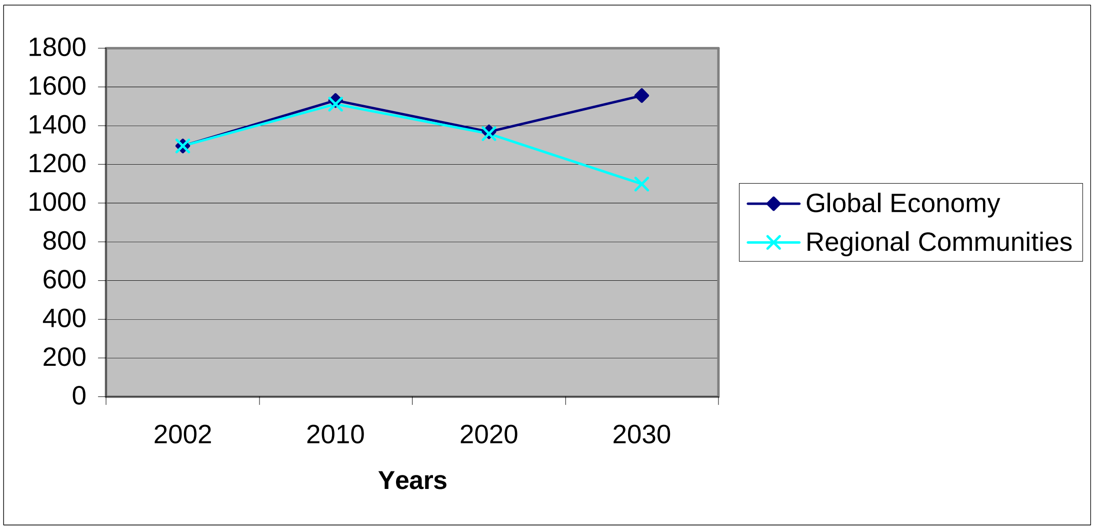

Figure 16: Development of the gross margin (mil Euro) arable sector over the two scenario's (2002-2030)

Figure 16 shows the effect on gross margin in the arable sector. Under GE gross margin increases, whereas under RC gross margin decreases compared to the base. The latter is explained by relative low prices of final outputs and high prices of inputs, especially services.

Figure 17 shows the effects on gross margins in the dairy farming sector. Under GE gross margin in the dairy farming sector increases sharply. This is the combined effect of increased production and high prices of milk. Under RC the development of the gross margin in dairy farming is negative, but this changes after 2020. This is explained by the increased price of milk after 2020(see Figure 17).

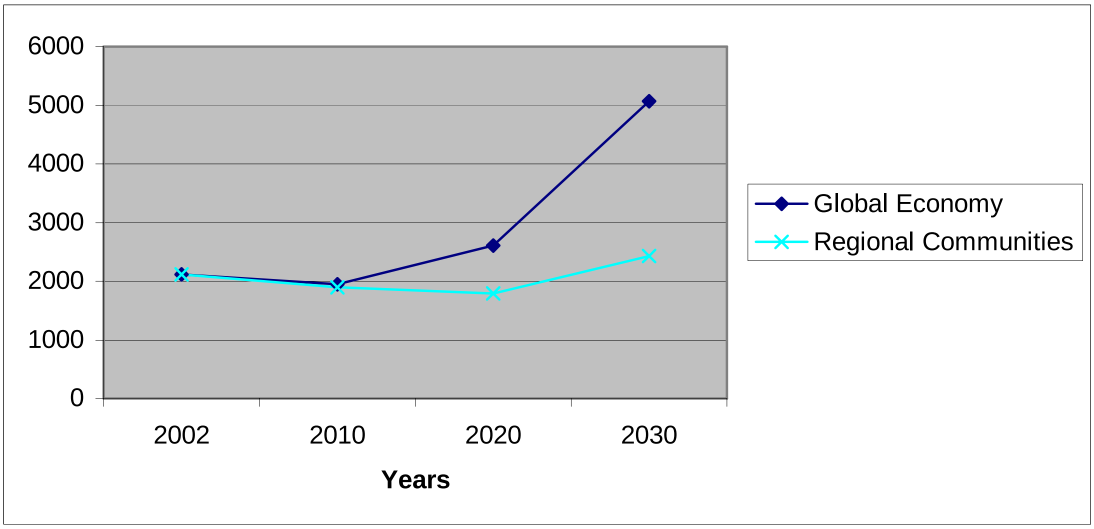

Figure 17: Development of the gross margin in dairy farming (mln Euro) arable sector over the two scenario's (2002-2030)

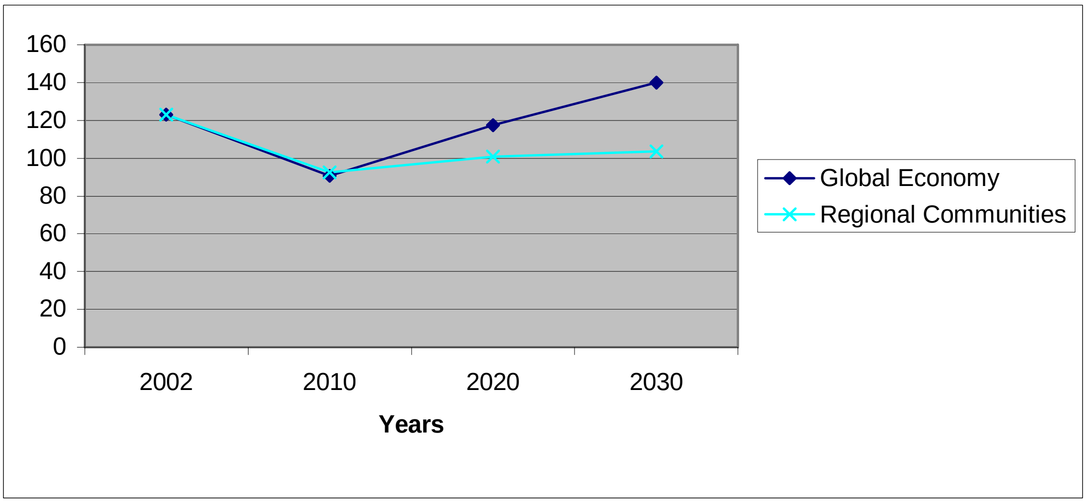

Figure 18: Development of the total surplus on the soil balance (kg N/ha) over the two scenario's (2002-2030).

Figure 18 shows the development of the nitrogen (N) surplus at the soil balance. After a sharp decrease in 2010, this environmental indicator is relatively stable under the RC scenario but increases under the GE scenario. The latter is explained by the increase in nutrients production from animal manure, that is not compensated for by increased processing of animal manure and export or by increased uptake of nutrients by harvested crops.

8. Conclusions

A coherent Land Use Planner - GTAP- DRAM link, has three advantages. First, it enables us to assess implications of the worldwide economic scenarios for the Dutch agricultural sector at the regional level. Secondly, it enables us to examine the economy wide consequences of policies and technological changes present in DRAM and absent in the GTAP model. Thirdly, it enables the endogenization of prices of output and input in DRAM consistent with global equilibrium conditions. In this way, we utilize the advantages of both modeling approaches: DRAM is specifically strong in generating agricultural supply response by region and by technology, whereas GTAP takes care of general equilibrium effects. Finally, use of Land Use Scanner makes possible endogenization of agricultural land availability and links the economic results with a GIS-based system making possible generation of spatially disggergated results.

The applied iterative linking procedure of the GTAP model and DRAM converges for most of the commodities. The most important difficulties that have been encountered when models were linked and solved are:

- *Differences in model structure, definition and specification of variables and units*

  As GTAP and DRAM have different objectives it is not surprising that model structure, definition and specification of variables and unities are different. Essentially, because the models have different objectives and domains, it is interesting to link the models and increase the domains of both models individually. Nevertheless, the results could be improved if definition and specification of variables were harmonized.
- *Differences in base situation*

  At the time the study was done a fully specified DRAM database was only available for 1996. In this study GTAP uses 2001 as the base year. It is recommended that both models use the same year as the starting position. It is also recommended to use average figures over a three to five year period, to take into account yearly fluctuations in yields in prices. These result for example from differences in weather circumstances.
- *Sometimes large differences in costs shares of different costs components per sector*

  The most important issue why both models behave differently is the differences in costs shares. It is recommended for future applications that costs shares are harmonized in both models before the models are linked.

Future combined application of DRAM and GTAP will consider recalibration of behavioral equations in GTAP, instead of using DRAM results as exogenous variables in GTAP. Moreover, convergence can be improved upon when demand elasticities derived from GTAP results are calculated as moving averages of different iterations.

The analysis of simulation results shows that the manure policy present in DRAM and absent in the GTAP model seriously affects the GTAP model results concerning production development of the Dutch agricultural sector. Manure policy is a very important issue in the Dutch livestock sector, as its regulations basically restrict the possibilities for production expansion. Moreover, the results show that the agricultural development depends greatly on the speed of overall economic development and less on the policy towards the agricultural sector. Therefore, plausibility of these macro-economic assumptions is very important for the quality of the projections.

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APPENDIX 1. Linkage of DRAM activities and inputs and GTAP sectors

Table A1. Linkage of DRAM activities and GTAP sectors

DRAM Activity	Description	GTAP Sector
MMLN	Medium milk production low nitrogen input cow hd	MILK
HMLN	High milk production low nitrogen input cow had	MILK
LMMN	Low milk production medium nitrogen input cow hd	MILK
MMMN	Medium milk production medium nitrogen input cow hd	MILK
HMMN	High milk production medium nitrogen input cow hd	MILK
MMHN	Medium milk production high nitrogen input cow hd	MILK
HMHN	High milk production high nitrogen input cow hd	MILK
LMHN	Low milk production high nitrogen input cow hd	MILK
MFBE	Beef cattle lu	CATTLE
FCAL	Fattening calves hd	CATTLE
SOWS	Sows hd	PIG_POL
PIGS	Pigs hd	PIG_POL
MOTP	mother animal meat poultry hd	PIG_POL
LHEN	Laying hens hd	PIG_POL
MPOU	Meat poultry hd	PIG_POL
HGRA	Grassland	GRO
HMAI	Fodder maize	GRO
HCER	Cereals ha	WHT
HPEA	Peas ha	CROPS
HSEG	Seed grasses ha	CROPS
HSEP	Seed potato ha	CROPS
HCPO	Consumption potato ha	CROPS
HSPO	Starch potato ha	CROPS
HSBI	Sugar beets ha	SUG
HONI	Onions ha	HORT
HFBU	Flower bulbs ha	HORT
HINV	Intensive vegetable ha	HORT
HEXV	Arable Horticulture vegetable combination ha	HORT
HFBI	Remaining fodder crops	GRO
HSAS	Set aside ha	CROPS
HAVC	Remaining arable crops ha	CROPS

Table A2. Linkage of DRAM inputs and GTAP sectors

DRAM Input	Description	GTAP Sector
SEPO	Seed potatoes	CROPS
CERE	Cereals	WHT
PEAS	Peas	CROPS

SEGR	Grasses seed	CROPS
FBEE	Fodder beets	GRO
CPOT	Consumption potatoes	CROPS
SPOT	Starch potatoes	CROPS
SBEE	Sugar beets	SUG
ONIO	Onions	CROPS
SASI	Set aside	CROPS
FBUL	Flower bulbs	HORT
INVE	Vegetable intensive	HORT
EXVE	Vegetable extensive	HORT
ARVC	Remaining arable crops	CROPS
MILK	Milk	MILK
BEEC	Beef from milking cows	MILK
BEEB	Beef from beef cattle	CATTLE
VEAL	Veal	CATTLE
SOWS	Meat from sows	PIG_POL
PIGM	Pig meat	PIG_POL
MOTP	Meat from mother animals	PIG_POL
LHEN	Meat from laying hens	PIG_POL
EGGS	Eggs	PIG_POL
POUM	Poultry meat	PIG_POL
BYPR	By products	CROPS
GRAS	Grass	GRO
MAIS	Fodder maize	GRO
NINO	Nitrogen	IND
PINO	Phosphor	IND
MANUDCOW	Manure from dairy cows	-
MANULMLN	Manure from lmln cow	-
MANUMMLN	Manure from mmln cows	-
MANUHMLN	Manure from hmln cows	-
MANULMMN	Manure from lmmn cows	-
MANUMMMN	Manure from mmmn cows	-
MANUHMMN	Manure from hmmn cows	-
MANUMMHN	Manure from mmhn cows	-
MANUHMHN	Manure from hmhn cows	-
MANULMHN	Manure from lmhn cows	-
MANUMOTP	Manure from mother animals	-
MANUSOWS	Manure from sows	-
MANULHEN	Manure from laying hens	-
MANUMFBE	Manure from beef cattle	-
MANUFCAL	Manure from fattening calves	-
MANUPIGS	Manure from pigs	-
MANUMPOU	Manure from meat poultry	-
YCOW	Calves for replacement milking cows	MILK

YFBE	Calves for replacement beef cattle	CATTLE
YMBE	Calves for replacement beef cattle	CATTLE
YFCA	Calves for replacement fattening calve CATTLE	CATTLE
YPIG	Piglets	PIG_POL
YPOU	One-day chicken	PIG_POL
YMOT	Young animals for replacement of mother animals	PIG_POL
YSOW	Young animals for replacement of sows	PIG_POL
YLHE	Young animals for replacement of laying hens	PIG_POL

There is no possibility to link prices and quantities of manure from livestock activities to GTAP sectors. Sector IND, as mentioned above includes all industry in GTAP.

APPENDIX 2. Calibration of DRAM model parameters

The base of DRAM is a supply model of agricultural outputs at the regional level. Steering mechanism of the mathematical programming model is profit maximizing behavior of producers and utility maximizing behavior of consumers in the model.

The model calibrates to observed activity levels in a base period, applying the approach of Positive Mathematical Programming (PMP), which is based on first order conditions (FOC) for an optimal solution. For activity i and region r, the FOC in the base is written as:

$$mr_{ir} = mc_{ir} = \alpha_{ir} + \beta_{ir} x_{ir}^{*} \qquad \forall i, r \qquad \text{(A1)}$$

Where:

mr_{ir} = marginal revenue of activity i in region r (euro per activity)

mc_{ir} = marginal costs of activity i in region r (euro per activity)

x_{ir}^{*} = level of activity i in region r (1000 head, hectare)

α_{ir} and β_{ir} are parameters to be calculated.

The variable mc_{ir} is obtained from the first step of the PMP approach. In the first step the model is written as a linear programming problem with constraints on the activity levels (Howitt, 1995). Marginal costs equal observed marginal costs plus unobserved marginal costs (the PMP variable). The latter is assumed equal to the shadow value on the activity constraints.

Because there are two parameters to be calculated and only one observation, namely one price and quantity pair, we can not calculate the parameters. To solve this problem, supply elasticities taken from literature are used to obtain extra information about the slope of the marginal cost function. The supply elasticity is written as:

$$\eta_{ir} = \frac{1}{\beta_{ir}} \frac{mc_{ir}}{x_{ir}^{*}} \qquad \forall i, r \qquad \text{(A2)}$$

where:

η_{ir} = supply elasticity of activity i in region r.

And the slope parameter is written as:

$$\beta_{ir} = \frac{mc_{ir}}{\eta_{ir} x^*_{ir}} \qquad \forall i, r \qquad \text{(A3)}$$

Now, parameters α_{ir} is simply calculated as:

$$\alpha_{ir} = mc_{ir} - \beta_{ir} x^*_{ir} \qquad \forall i, r \qquad \text{(A4)}$$

An extensive discussion of the calibration of DRAM to observed activity levels in a base period can be found in Helming (2005).

To continue the calibration procedure presented above, the FOC for activity i are written as:

MCi	=	MRi	(A5)
MCi	=	ACTCOSTi+PMPi	(A6)
MRi	=	SALESi+INCPAYi+SALESMANi+SALESYAi+ SALESROUi-QUOTCOSTi-LANDCOSTi	(A7)

where:

MCi	=	marginal cost per activity i (euro per activity)
ACTCOSTi	=	variable cost per activity i (euro per activity)
PMPi	=	unobserved cost per activity i (PMP variable) (euro per activity)
MRi	=	marginal revenue per activity i (euro per activity)
SALESi	=	sales of final outputs per activity i (euro per activity)
INCPAYi	=	direct income payments per activity i (euro per activity)
SALESMANi	=	net-sales of manure, including costs of mineral fertilizers and income from manure acceptation per activity i (euro per activity)
SALESYAi	=	net sales of young animals per activity i (euro per activity)
SALESROUi	=	net sales of roughage per activity i (euro per activity)
QUOTCOSTi	=	shadow value of quota rent per activity i (euro per activity)
LANDCOSTi	=	shadow value of land per activity i (euro per activity)

To map results from GTAP into DRAM the parameters of the marginal cost equation (A1) could be calculated from input (labor, capital, land, intermediates) price and productivity changes used by activity i given by GTAP, see equation (A6), but also from price and productivity changes of inputs and outputs used and produced by activity i, see equation (A7). In this study the latter approach is used.

APPENDIX 3. GTAP-DRAM results, iteration 0

Price and productivity changes per activity and changes of activity levels are taken from GTAP. Net sales of manure, including costs of mineral fertilizers is kept constant to the base period values. Shadow prices of quota (milk, sugar beet, starch potatoes) follow the prices of sectoral outputs derived from GTAP. Land price developments per period and scenario are also taken from GTAP. Table A3 below shows the changes in sectoral output prices and productivity in the first period under RC scenario.

Table A3. Changes in productivity (outq), sectoral output prices (outp) and land prices in period 2002 to 2010 under RC scenario (percentages per year)

sector	wheat	grains	sugar	horticu-ture	crops	cattle	pig and poultry	milk
outq	0.74	0.77	0.34	0.52	0.49	0.3	0.3	0.5
outp	-0.34	-0.1	0.05	-0.43	-0.6	0.04	-0.56	-1.55

Table A3 shows that real prices of milk decrease with 1.55 percent per year. Prices of cattle are about equal and prices of pigs and poultry decrease with almost 0.56%. Productivity changes are defined as changes in output per hectare or animal in DRAM. This is different from GTAP and as a result productivity changes in the sectors cattle, pig and poultry and milk are added exogenous (Table A3). The changes in the price of land and mineral fertilizer equal 4.19 per cent per year and -0.53 per cent per year respectively. The change in milk production per hectare equals –0.53 per cent per year.

Table A4 shows the changes in activity levels per year used to calibrate the supply functions in DRAM in iteration 0. Not everything is taken from GTAP. It is assumed that the substitution to activities HONI, HINV, HEXV, HSEP and HCPO are limited by the CAP Reform 2003. Moreover, development of the flower bulb sector (HFBU) follows an exogenous trend.

Table A4: Changes in activity levels in period 2002 to 2010 under RC scenario (percentages per year)

LMLN,MMLN,HMLN,LMMN,MMMN,HMMN,MMHN,HMHN,LMHN	-0.33
MFBE	0.06
FCAL	0.06
SOWS	0.71
PIGS	0.71
MOTP	0.71
LHEN	0.71
MPOU	0.71
HGRA	-1.17
HMAI	-1.17
HCER	-1.10
HFBI	0.04
HPEA	0.04
HSEG	0.04
HAVC	0.04
HSBI	-0.35
HSPO	0.04
HONI,HINV,HEXV)	0.00
HSEP,HCPO	0.00
HFBU	0.50
HSAS	-2.00

Table A5. Agricultural activities under scenario RC (iteration 0)

Agricultural activities per period (1000 hectare or animals)					DRAM: changes per period %			GTAP: changes per period %		
	2002	2010	2020	2030	2010	2020	2030	2010	2020	2030
MFBE	320	213	330	318	-33.51	54.90	-3.55	0.56	-2.91	-3.72
FCAL	712	684	704	678	-3.97	2.98	-3.80	0.56	-2.91	-3.72
SOWS	1007	1023	1046	965	1.57	2.22	-7.66	6.78	-3.72	-7.37
PIGS	5590	5338	5900	5429	-4.51	10.53	-7.98	6.78	-3.72	-7.37
MOTP	4949	5227	5080	4706	5.61	-2.80	-7.36	6.78	-3.72	-7.37
LHEN	28680	28233	29194	28142	-1.56	3.40	-3.60	6.78	-3.72	-7.37
MPOU	54660	57738	55476	51288	5.63	-3.92	-7.55	6.78	-3.72	-7.37
HCER	234	177	141	129	-24.35	-20.31	-8.69	-9.49	-7.27	-3.57
HPEA	10	9	8	7	-11.63	-10.75	-5.64	0.39	-3.08	-1.64
HSEG	29	26	22	21	-11.85	-14.88	-5.54	0.39	-3.08	-1.64
HSEP	39	37	37	37	-4.60	-0.62	0.00	0.39	-3.08	-1.64
HCPO	77	74	73	72	-4.24	-1.89	-0.09	0.39	-3.08	-1.64
HSPO	49	44	45	46	-11.14	2.63	3.46	0.39	-3.08	-1.64
HSBI	109	106	100	94	-2.68	-6.09	-5.53	-3.10	-6.48	-5.82
HONI	21	21	20	20	-2.53	-0.96	-0.04	0.39	-3.08	-1.64
HFBU	24	25	26	28	3.14	4.98	5.54	-4.79	-3.23	-2.24
HINV	19	19	19	19	-1.24	-0.30	0.00	-4.79	-3.23	-2.24
HEXV	26	26	25	25	-2.14	-0.74	0.00	-4.79	-3.23	-2.24
HFBI	7	6	6	6	-6.21	-5.79	-0.08	-5.17	-19.39	-4.21
HSAS	6	3	1	1	-50.00	-49.98	-50.00	nvt	nvt	nvt
HAVC	34	32	29	28	-7.10	-7.82	-2.91	0.39	-3.08	-1.64
LMLN	273	257	234	244	-6.06	-8.77	4.09	-3.00	-4.50	-4.50
MMLN	82	84	81	75	1.89	-3.09	-6.97	-3.00	-4.50	-4.50
HMLN	31	32	30	27	3.75	-5.55	-9.50	-3.00	-4.50	-4.50
LMMN	267	248	256	251	-7.43	3.46	-2.10	-3.00	-4.50	-4.50
MMMN	277	279	277	245	0.93	-0.92	-11.46	-3.00	-4.50	-4.50
HMMN	71	71	63	57	0.13	-10.82	-10.52	-3.00	-4.50	-4.50
LMHN	192	177	166	162	-7.70	-5.92	-2.45	-3.00	-4.50	-4.50
MMHN	198	195	177	169	-1.32	-9.20	-4.51	-3.00	-4.50	-4.50
HMHN	95	99	89	84	4.70	-10.88	-5.81	-3.00	-4.50	-4.50
HGRA	218	198	228	236	-9.08	14.76	3.60	-10.02	-6.98	-1.55
HMAI	82	51	43	33	-37.90	-15.31	-22.20	-10.02	-6.98	-1.55

nvt means that there is no comparable variable in GTAP.

Table A5 shows detailed results of GTAP-DRAM iteration 0, concerning agricultural activity levels in the different periods under the RC scenario. The changes in activity levels per period can be quite different from the initial changes taken from GTAP (Table A4) for the following reasons:

- In the first period (2002-2010) production in the intensive livestock industry in DRAM is different from production changes of the pigs and poultry sector in GTAP. This is explained by the increase in the manure prices and manure disposal costs in the pigs and poultry sector, not taken into account in GTAP.
- A change in manure policies in the first period also affects land use. This is because manure application limits are different per crop. In practice, manure application limits are relative high on grassland and fodder maize and relative low on arable crops. This explains the relative large decrease in cereal crops (HCER) in DRAM compared to GTAP.
- The development of the number of dairy cows per type (LMLN, MMLN,…,HMHN) can be quite different from the initial average development of dairy cow numbers from GTAP. In the first period there is a relative shift towards high productive dairy cows. This is explained by relative low prices of milk quota and high costs of animal manure. Especially in the third period there is a shift towards relatively low productive dairy cows. This is due to the decreasing number of dairy cows and the (relatively) increasing availability of land.
- After a sharp decrease in the number of beef cattle in the first period, the number of beef cattle recovers in the second period. This is explained by the

further decrease in cereal crops, the increase in the acreage of roughage crops, the decrease in the costs of animal manure and the decrease in the costs of grass and maize.

Some general reasons why the results from DRAM are different from the results of GTAP:

- Differences in cost shares of land and quota costs in total variable and factor costs in DRAM and GTAP;
- Differences in revenue shares in DRAM and GTAP;
- Exogenous land supply in DRAM. This means that availability of land is more restrictive in DRAM than in GTAP;
- Another difference is that in the exercise presented below decoupled direct payments in DRAM are treated as a lump sum payment. In GTAP direct payment are transformed into factor subsidies;

APPENDIX 4. GTAP aggregation

Table A6. Region aggregation

Region	Description	Original the GTAP model v 6.4 regions
belu	Belgium and Luxembourg	Belgium; Luxembourg.
Dnk	Denmark	Denmark.
Deu	Germany	Germany.
Grc	Greece	Greece.
Esp	Spain	Spain.
Fra	France	France.
Irl	Ireland	Ireland.
Ita	Italy	Italy.
Nld	The Netherlands	Netherlands.
Aut	Austria	Austria.
Prt	Portugal	Portugal.
Fin	Finland	Finland.
Swe	Sweden	Sweden.
Gbr	United Kingdom	United Kingdom.
euis	Cyprus, Malta	Cyprus; Malta.
Cze	Czech Republic	Czech Republic.
euba	EU Baltic countries	Estonia; Latvia; Lithuania.
Hun	Hungary	Hungary.
Pol	Poland	Poland.
Svn	Slovenia	Slovenia.
Svk	Slovakia	Slovakia.
apeu	EU applicants countries	Bulgaria; Romania.
reur	Resf of Europe	Switzerland; Rest of EFTA; Rest of Europe; Albania; Croatia.
Fsu	Former Soviet Union	Russian Federation; Rest of Former Soviet Union.
Tur	Turkey	Turkey.
Usa	USA	United States.
Can	Canada	Canada.
Cam	Central America	Mexico; Rest of North America; Central America; Rest of FTAA; Rest of

		the Caribbean.
Sam	South America	Colombia; Peru; Venezuela; Rest of Andean Pact; Argentina; Brazil; Chile; Uruguay; Rest of South America.
Oce	Australia, New Zealand	Australia; New Zealand; Rest of Oceania.
Jap	Japan	Japan.
Eas	East Asia	China; Hong Kong; Korea; Taiwan; Rest of East Asia.
seas	South-East Asia	Indonesia; Malaysia; Philippines; Singapore; Thailand; Vietnam; Rest of Southeast Asia; Bangladesh; India; Sri Lanka; Rest of South Asia.
meast	Rest of Middle East	Rest of Middle East.
Naf	North Africa	Morocco; Rest of North Africa
Caf	Central Africa	Rest of SADC; Uganda; Rest of Sub-Saharan Africa.
saf	South Africa	Botswana; South Africa; Rest of South African CU; Malawi; Mozambique; Tanzania; Zambia; Zimbabwe.

Table A7. Sector aggregation

Sector	Description	Original the GTAP model v 6.4 sectors
wht	Wheat	Wheat.
gro	Cereal grains nec	Cereal grains nec.
oil_seed	Oil seeds	Oil seeds.
sug	Sugar cane and beet, sugar	Sugar cane, sugar beet.
hort	Vegetables, fruit, nuts	Vegetables, fruit, nuts.
crops	Other crops	Paddy rice; Plant-based fibers; Crops nec.
cattle	Cattle,sheep,goats,horses	Cattle,sheep,goats,horses.
pig_pol	Animal products nec	Animal products nec.
milk	Raw milk	Raw milk.
beef	Meat:cattle, sheep,goats,horses	Meat: cattle,sheep,goats,horse.
pork_pol	Meat products nec	Meat products nec.
oils	Vegetable oils and fats	Vegetable oils and fats.
dairy	Dairy products	Dairy products.
sugar	Sugar	Sugar.
feed	Food products nec	Food products nec.
agro	Other agr-food products	Wool, silk-worm cocoons; Forestry; Fishing; Processed rice; Beverages and tobacco products.
ind	Industry	Coal; Oil; Gas; Minerals nec; Textiles; Wearing apparel; Leather products; Wood products; Paper products, publishing; Petroleum, coal products;

ser	Services	Chemical,rubber,plastic prods; Mineral products nec; Ferrous metals; Metals nec; Metal products; Motor vehicles and parts; Transport equipment nec; Electronic equipment; Machinery and equipment nec; Manufactures nec. Electricity; Gas manufacture, distribution; Water; Construction; Trade; Transport nec; Sea transport; Air transport; Communication; Financial services nec; Insurance; Business services nec; Recreation and other services; PubAdmin/Defence/Health/Educat; Dwellings.

APPENDIX 8. Scenarios macro-assumptions

Table A8. GDP and population yearly growth rates in 2001 – 2030

	GDP		POP	
	GE	RC	GE	RC
belu	2.6	0.8	0.2	-0.1
dnk	2.7	1.1	0.3	0.0
deu	2.2	0.6	0.1	-0.2
grc	2.6	0.9	0.2	-0.2
esp	3.1	0.9	0.1	-0.3
fra	2.7	0.8	0.4	0.0
irl	3.3	1.6	0.8	0.5
ita	2.1	0.2	0.0	-0.4
nld	2.7	1.0	0.6	0.1
aut	2.5	0.8	0.1	-0.2
prt	2.6	0.9	0.2	-0.2
fin	2.6	1.0	0.2	-0.1
swe	2.7	1.0	0.2	0.0
gbr	2.4	0.9	0.3	0.0
euis	3.1	1.3	0.7	0.2
cze	3.2	1.0	0.1	-0.5
euba	3.8	1.5	-0.1	-0.7
hun	3.1	0.8	-0.2	-0.8
pol	3.6	1.3	0.2	-0.4
svn	2.5	0.8	0.1	-0.5
svk	4.0	1.6	0.3	-0.3
apeu	5.2	1.9	-0.1	-0.9
reur	2.8	0.8	0.4	-0.1
fsu	4.0	1.4	0.0	-0.8
tur	5.2	3.0	1.3	0.7
usa	2.7	1.6	0.8	0.7
can	2.7	1.5	0.5	0.6
cam	4.1	3.1	1.0	1.1
sam	3.7	2.8	1.0	1.1
oce	2.4	1.2	0.2	0.3
jap	1.7	0.6	0.0	-0.1
eas	6.1	4.5	0.3	0.6
seas	5.3	4.2	0.9	0.9
meast	4.4	3.2	1.7	1.5
naf	5.2	4.0	1.6	1.5
caf	6.3	3.9	2.1	2.4
saf	5.1	3.0	2.1	2.4