A model of Dutch agriculture based on Positive Mathematical Programming with regional and environmental applications

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Abstract

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The purpose of this thesis is to describe the current state-of-the-art of the Dutch Regionalized Agricultural Model (DRAM). DRAM can be defined as a comparative static, partial equilibrium, mathematical programming and regionalized model of the Dutch agricultural sector with environmental aspects. The focus of DRAM is to model the allocation of a number of fixed inputs over different agricultural products and on the formation of market prices at the regional level. DRAM includes features such as Positive Mathematical Programming (PMP), endogenous prices of animal manure, manure transport between regions and possible technology changes in dairy farming. The second purpose of this thesis is to provide a detailed presentation and discussion of the database and benchmark results. Finally, the results of two model applications are presented. The model is applied to analyze the economic and some selected environmental effects of changes in the EUs Common Agricultural Policy (CAP) and Dutch manure and nutrients policies. It is concluded that the model is a flexible tool for integrated scenario and policy analyses at the agricultural sector level.

Voorwoord

Toen ik ruim elf jaar geleden bij het LEI begon, had ik niet gedacht nog eens een proefschrift te schrijven. Eindelijk zou ik te weten komen hoe het LEI toch altijd aan die berekeningen komt en zou ik direct toegang krijgen tot hét boekhoudnet van het LEI, het huidige BedrijvenInformatie Net (BIN). Ik ging werken aan een model voor de Nederlandse landbouwsector, namelijk het Dutch Regionalized Agricultural Model (DRAM), vanuit een ver verleden bekend als het model Bakker, vernoemd naar de eerste ontwikkelaar, wijlen dr. Th. M. Bakker. Vanwege een vacaturestop had dit werk een hele tijd stil gelegen en ik kreeg de kans om het model te actualiseren en opnieuw op te zetten. Daarbij maakte ik gebruik van het werk van mijn voorgangers en ik heb mijn best gedaan daar iets aan toe te voegen, vaak ook samen met anderen. Een groot dank-je-wel aan alle personen die mij hebben gesteund en geholpen, is dan ook wel op zijn plaats.
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Den Haag, december 2004

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1. Introduction

1.1 Background

Agricultural production and profits from agriculture in the Netherlands are partly dependent on the Common Agricultural Policy (CAP) of the European Union (EU). This is especially true for dairy, arable and beef and veal production. In 1992 the CAP was fundamentally reformed, the so-called MacSharry reform. The MacSharry reform included an historical switch from price support to direct payments in the arable and beef sector. The direct payments, linked to headage and hectares, compensated for lower profits due to market liberalization measures (lower price support for arable and beef products). In 1999 the European Council agreed new reforms of the CAP, the so-called Agenda 2000 agreements. The Agenda 2000 package was seen as a further step in the process of reforming the CAP in view of challenges in the years ahead: enlargement of the EU, a new round of trade liberalization negotiations, increased public concerns regarding negative externalities and a higher awareness of positive ones. Agenda 2000 included further market liberalization measures in the arable and beef sector (European Commission, 1999a, 1999b, 1999c and 2000). Again, lower profits were partly compensated for by an increase in existing direct payments. The Agenda 2000 package initiated a rather limited milk market reform. Under Agenda 2000 the milk quota system was extended for at least another 6 years. In 2005 intervention prices would be decreased by 15% in three steps of 5% annually. Dairy farmers would receive part compensation through direct payments per kilogram of milk and by means of a national envelope. In the Agenda 2000 agreement, a mid-term review (MTR) was anticipated in 2002 to review the policy reforms. In 2002 the European Commission proposed some options to further reform the EU dairy policy. Options ranged from no further reform after the implementation of Agenda 2000 to milk quota abolishment in 2006. Moreover, the Commission proposed to decouple from agricultural production current direct payments in the beef and arable sectors and future direct payments in the dairy sector (European Commission, 2002).

Following the Commissions MTR proposals, the European ministers of agriculture agreed on further CAP reform on 26 June 2003, here referred to as CAP Reform 2003 (European Commission, 2003). Important for the dairy sector is that the reform entails a reduction of 15% in intervention prices for skimmed milk powder (in three steps of 5% annually from 2004 to 2006) and 25% for butter (three steps of 7% annually from 2004 to 2006 and 4% in 2007). Moreover, a prolongation of the milk quota system until 2014/15 was agreed in combination with a milk quota increase (in the Netherlands) of 1.5% in three steps of 0.5% annually starting in 2006. Dairy farmers will be compensated with a decoupled direct payment of €35.50 per ton. Last but not least, the Commission's proposal to fully or at least partly decouple existing direct payments in the arable and beef and veal sector, was accepted by the European ministers of agriculture.

Another important issue for profits and production in Dutch agriculture, especially for livestock production, is the European Nitrate Directive (91/676/EEC) and its translation to national manure and nutrients policies. The purpose of the Nitrate Directive is to reduce water pollution caused or induced by nitrates from agricultural sources and to prevent further such pollution.

In the Netherlands already in the early 1980s, it became clear that the contribution of the agricultural sector to environmental pollution by manure and nutrients surpluses was more severe than had been assumed. The problem of manure and nutrients surpluses in the Netherlands, especially at livestock farms, is explained by the high intensity of agricultural production and by farm and regional specialization. In the Netherlands livestock production is concentrated at specialized livestock farms. These farm types are especially concentrated in the sand regions in the south and east of the country. Crop production is concentrated in the clay regions in the north and southwest. Production in both cattle farming and the intensive livestock industry is largely based on imported concentrates from outside the EU at relatively low prices compared to prices for EU produced feed grains. As a result excess amounts of manure are produced on livestock farms according to prevailing legislation (Brouwer and Van Berkum, 1996). The farms themselves use a proportion of livestock manure while excess amounts are transported to neighboring farms with a lower stocking density. Another proportion of livestock manure is also transported to other regions.

Alternatively, excess amounts of manure may also be exported to surrounding countries or may be processed in factories. However, the costs involved in such transport to other regions, manure exports and processing are substantially higher than the costs involved in using the manure within the region. Furthermore, arable crop production is to a large extent based on purchased mineral fertilizer because of their relatively low prices. The low prices of mineral fertilizers have also stimulated intensity of the cropping plan at the average arable farm, which means that in the past low nutrients input crops (e.g. cereals) are substituted with high nutrients input crops (e.g. potatoes and sugar beets).

The Dutch government initiated manure and nutrients policies in the 1980s and they have been further developed ever since. Ahead of a definitive legislation to control the nutrients surplus, the 'Interim Law to the Restriction of Pigs and Poultry Farms' (Interim Law) was passed as far back as November 1984. This law prohibited the start of new pig and poultry farms in eastern and southeastern regions (the manure concentration areas or remains areas). Expansion of existing farms in the manure concentration areas was prohibited to a limit of ten percent. The Interim Law did not have the desired effect. After its introduction the nutrients surplus problem increased.[1] The Dutch government was forced to intervene and new policies have been launched ever since.

In 1998 the so-called Mineralen Administratie Systeem (MINAS), a nutrients accounting system, became compulsory for farms with high livestock densities (more than 2.5 livestock units per hectare). MINAS calculates the input (e.g. through the purchase of feed, nutrients from mineral fertilizers and animal manure) and the output of nutrients (e.g. through the sale of milk, meat, cereals and manure) at the farm level. Nutrient surpluses above a certain threshold level are taxed. Threshold levels are different per soil type and crop to take into account differences in environmental impact. In 2001 MINAS became compulsory for all farmers including arable farmers and other open-field producers. Moreover, in 2002 an additional obligation to remove nutrients surplus from the farm was introduced. Under this obligation producers of

[1] In the period from 1984 to 1987 the intensive livestock industry increased by almost 25 percent. The production of slurry increased by 6 million metric tons (30 percent).

animal manure without sufficient manure application capacity have to contract additional capacity from landowners. This can be done directly or indirectly through a middleman. The nitrogen (N) of animal manure application standard equals 170 kg N per hectare for arable land and 250 kg N per hectare for grassland. As part of MAO, the government decided that as of 2003 application capacity needs to be found and contracted for 85% of manure and nutrients production on the farm (Ministry of Agriculture, Nature Management and Fisheries, 2002).

1.2 Agricultural sector models: definition and model requirements

Agricultural sector models can be used to analyze effects of policy changes for different agricultural industries and the agricultural sector as a whole. Moreover, agricultural sector models can conduct policy experiments in order to assess policy alternatives before a political decision is taken and put into operation (Weber, 2003). Burrell (1995) defines an agricultural sector model as an abstract, quantified framework for organizing various kinds of information about the structure and functioning of the agricultural sector. Weber (2003) describes an agricultural sector model as an intermediate approach between an economy-wide model and partial commodity market models, by means of which the implications of the multi-input multi-output nature of agricultural production, joint factor use and own-production of intermediate inputs can be investigated by depicting the causal links and behavioral responses within the sector.

Sector models concentrate on the effect of policy and technology changes on the allocation of inputs and prices. The requirements of an agricultural sector model are provided by the demand for explicit policy modeling and can be different for different purposes. Explicit policy modeling is the possibility to fix model variables exogenously, in the same way as they are actually fixed by the policy makers (Salvatici et al., 2001). New measures included in the CAP are more and more modulated at the regional or even the farm level. Therefore, explicit policy modeling probably requires an agricultural sector model that comprises sub models for each firm and consumer in the sector or even the economy. These sub models need to be interlinked and solved simultaneously to take into account possible market effects of changes in aggregated supply and demand (Taylor and Howitt, 1993). Although computer hardware and software have improved considerably over the last decades, this ideal approach is obviously still not feasible. According to Burrell (1995) there is a trade-off between the ever-increasing list of policy questions on the one hand, and empirical and computational feasibility, cost, transparency, timeliness and performance of the model on the other hand.

Hazell and Norton (1986) give five structural elements, which should be explicitly or implicitly included in an agricultural sector model:

1. A description of the behavior of the producers. In what way do they decide on their production plan, on how to produce and where. Most models assume profit-maximizing behavior of the producers, but other considerations could be assumed as well e.g. risk minimization.
2. A description of the technology set or conditions under which production takes place. Because of the heterogeneity of the agricultural sector and because many commodities are related both on the demand and supply side of the market, a large number of commodities should be included. To further increase the model's capability to describe reality, it should allow to produce the same type of output under different input-output relationships. Firstly this is necessary because of observed differences in production possibilities at the regional and farm levels, and secondly to guarantee the flexibility of the model to react to relative price changes. In other words, substitution between inputs should be possible.
3. A description of the available fixed inputs capital, land and labor.
4. A description of the market environment. It should be specified which inputs and outputs are available at the sector level at fixed prices (fully elastic supply and demand) and what relevant agricultural markets of inputs and outputs are characterized by inelastic or not wholly elastic demand and supply at the sector level. International trade of price endogenous inputs and outputs should be described by import-supply and export-demand functions.
5. A description of the policy environment. The policy variables in the model should be a function of the policy questions at hand. Moreover, following the principles of explicit policy modeling, they should be closely related to the policy variables fixed by the policy makers or other institutions.

Given these general elements, the required model specification is determined by the specific economic problem at hand. For our purposes, we come back to this in section 1.4, the model should allow an analysis of economic and environmental effects of the latest Dutch manure and nutrients policies at regional and industry levels. This requires among other things the modeling of animal manure markets. Different farm types should be identified as well. This is especially important because of possible differences in behavior with respect to manure demand and supply. Moreover, MINAS, an important element of manure and nutrients policies in the Netherlands after 1998, is defined at the farm level.

1.3 Historical overview of DRAM

This thesis further develops and applies the so-called Dutch Regionalized Agricultural Model (DRAM). DRAM is a mathematical programming agricultural sector model, which was first developed at Agricultural Economics Research Institute (LEI) in The Hague in the late 1970s and early 1980s. The choice to develop an agricultural sector model based on the mathematical programming approach was motivated by the following arguments: (1) mathematical programming models of economic sectors are especially well suited for interdisciplinary research because they include technical coefficients which characterize production processes as well as market conditions (2) mathematical programming models are capable to handle numerous cross-effects as competition for the same resources (3) demand for information about factors connected with agricultural production as land use, livestock numbers, manure production, land values, use of inputs, etc. To keep the model size manageable agricultural sector was defined in terms of agricultural activities (production lines) and the modeling of individual farms was excluded.

DRAM was first developed and used to analyze the situation of autarchic food-supply under emerging energy-scarcity (Bakker, 1985). This early version of DRAM primarily focused on a technical representation of agricultural and food production in the different regions in the Netherlands. The second application of DRAM was to analyze the possibilities of so-called integrated agricultural production systems in the Netherlands (Van der Wal, 1985; Bakker, 1986). DRAM was adjusted to include economic relationships: costs and revenues on the one hand and market clearing processes and behavior on the other hand. The Dutch Scientific Council for Government Policy (WRR) initiated the study. DRAM was also used to analyze the economic and environmental effects of different policy options in the dairy sector to control milk production in the Netherlands. The study was a co-production with the Center of Environmental Science of the University of Leiden and focused on the relationships between agriculture and environment (de Graaf and Tamminga, 1990). So far it appeared that DRAM was very useful to start discussions concerning economic and environmental effects of policy and technology changes. The study on integrated agriculture mentioned above triggered broad and intensive discussions on agricultural production systems integrating economy and environment (NRLO, 1999).

An important shortcoming of DRAM was that the model was not calibrated to observed activity levels. The development of a base or benchmark, a model result describing the base period that can be used as the comparison base for other scenarios, was very time consuming and ultimately based on flexibility constraints (lower and upper bounds) on activity levels.

After 1993, DRAM was fully modified and rewritten into GAMS (General Algebraic Modeling System) (Brooke, et al., 1992). The database was up-dated and extended to include alternative technologies for different production activities. This new version of DRAM was used to analyze the effects of environmental measures on the Dutch agricultural sector (Helming, 1997). Regional specific price elasticities of demand were used to explain the allocation of resources and agricultural production across the regions. This improved the flexibility of the model, but the approach was insufficient to fully calibrate the model to observed activity levels in the base period.

An important step therefore was the model's full calibration to observed activity levels using the method of Positive Mathematical Programming (PMP) (Howitt, 1995a, 1995b, and 2002). With PMP it was possible to overcome the normative character of the mathematical programming model. The central hypothesis of PMP is that resource allocations that are not constrained by resources or empirical constraints, result from first-order conditions of profit maximizing behavior. The most important contribution of PMP is that these types of models calibrate precisely to observed activity levels, but are free to respond to changes in competitive equilibrium induced by policy or resource changes (no flexibility constraints).

By modifying the model, including the improved calibration procedure, DRAM became an interesting tool for integrated scenario and policy analyses at the Dutch agricultural sector level. This is demonstrated by its contributions to policy decision-making and discussions in general. Effects of the decoupling of direct payments as investigated by DRAM are referred to in letters from the Dutch minister of Agriculture to the Dutch Parliament (Ministry of Agriculture, Nature Management and Fisheries, 2003 and 2004). Other studies fully or partly based on the modified and calibrated DRAM are the following:

- analyses of the future development of Dutch agriculture at national and regional levels (van Everdingen et al., 1999; Goetgeluk et al., 1999; Hillebrand and Koole, 1999; de Bont, et al., 2001).
- analyses of changes in the CAP e.g. abolition of milk and sugar quota and decoupling of direct payments (Helming, 1997a, Helming and van Leeuwen, 1999; Brouwer and Helming, 2000; Berkhout et al., 2002; de Bont et al., 2003a, 2003b, 2003c, 2003d; Berkhout et al., 2003).
- analyses of alternative manure and nutrients policies (Helming, 1996, 1997b, 1998).
- analyses of climatic changes (Kuik et al., 2000).

DRAM concentrates on allocation of fixed inputs and agricultural market prices and their effects on agricultural production and profits at the regional and sector levels. Agricultural production is defined in terms of agricultural activities at the regional level. In doing so, the modeling of behavior at farm level, the number of farms or farm size is excluded. This is due to reasons of simplicity. The focus of DRAM on effects at the sector and regional levels limits computation time to a maximum of about five minutes (depending on the scenario). Model adjustments to the prevailing state-of-the-art, a limited computation time and therefore a relative limited use of financial resources has proven to be an important precondition for the handling, success and continued use of DRAM.

Many different types of sector models and approaches are available. For an overview of different types of sector models and approaches see Taylor and Howitt (1993), Burrell (1995), Van Tongeren (2001) and Lehtonen (2001). The current version of DRAM belongs to the class of comparative static, partial equilibrium and mathematical programming models. Partial equilibrium means that DRAM describes market equilibrium for some selected (agricultural) input and output markets (e.g. manure market) and there is no feedback between the agricultural industry and the rest of the economy. Moreover, comparative static equilibrium models assume that production and consumption fully and instantaneously adjust to policy changes until a new equilibrium is found. Comparing this new equilibrium with the initial situation shows medium term policy effects. Hence, comparative static equilibrium models do not show a time path so they cannot be used to simulate cumulative response to a policy change as it occurs over a number of linked time periods (Burrell, 1995). Moreover, whether this new equilibrium is actually reached also depends on the assumption that exogenous variables are constant during the adjustment period.

1.4 Objectives

The objectives and scientific contributions of this thesis are:

1. to give a description and detailed mathematical presentation of the current version of DRAM. Special attention is paid to the modeling of manure markets and possible technology switches in dairy farming in combination with model calibration using the approach of Positive Mathematical Programming (PMP);
2. to give a detailed description of the underlying database of DRAM. In the base, DRAM provides a description of agricultural production and input use in the Netherlands in 1996. Regional manure transport, manure prices and some selected environmental variables as calculated by DRAM will be validated against observed data in the base period.
3. to apply DRAM and to analyze the economic and environmental effects of recent EU CAP changes on different agricultural industries in the Netherlands, the agricultural sector and the economy as a whole. The policy application includes elements of both Agenda 2000 (most important for the arable and beef sectors) and CAP Reform 2003 (most important for the dairy

sector). Moreover, the effects of decoupling of direct payments are analysed as well as the effects of complete abolition of the milk quota system and price support.

4. to apply DRAM and to analyze the economic and environmental effects, from nutrients from animal manure application standards in 1996 to MINAS nutrients loss standards and nutrients from animal manure application standards given by MAO in 2004. Especially in this chapter the effects of manure markets on agricultural production will be shown.

Objective 1 is to give a general overview and motivation of the variables specified and choices included in the current version of DRAM. In addition, a detailed mathematical presentation of the model is also necessary because such a detailed description is at present not available. Furthermore, an important new feature of DRAM is the inclusion of manure markets for different types of animal manure. So far the steering role of manure prices for profits and allocation of resources and composition of agricultural production was not entirely clear and had been described within the framework of an agricultural sector model. Therefore, an important part of this thesis is devoted to explaining how to model and explain manure prices. To achieve this and to explain the models' driving forces in general we will describe both the primal Non Linear Programming (NLP) version of DRAM and the corresponding dual NLP version of DRAM in detail. The primal version gives a technology description of how inputs are related to outputs. The dual version gives insights into how (shadow) prices of inputs are related to (shadow) prices of outputs. The dual model more clearly shows the steering mechanism of the model as the first order conditions of profit maximization are modeled explicitly. Calibration of DRAM is based on the Positive Mathematical Programming (PMP) approach (Howitt, 1995a, 1995b and 2002). The specific PMP procedure that is applied here will also be described in detail.

Mathematical programming models like DRAM are very data intensive. Objective 2 of this thesis is to discuss the most relevant data used in DRAM in the base period. An important requirement of DRAM is to simulate manure market prices and quantities. Manure markets affect agricultural production in the Netherlands because of the intensity of livestock production and restrictive manure and nutrients policies.

Therefore we will focus on important manure and nutrients variables that are taken into account in DRAM. Moreover, results from DRAM calculations as regional manure transport and manure prices in the base or benchmark, will be validated against observed regional manure transport and manure prices in the base period (1996).

Objective 3 is to analyze the ceteris paribus environmental and economic effects of the most recent EU CAP changes included in Agenda 2000 (most important for arable and beef sectors) and CAP Reform 2003 (most important for the dairy sector). Although there are differences with respect to the time-schedule of the different policy measures, all changes are simulated as if they were introduced in the base at the same time with exogenous variables put at base value levels (1996). The CAP reform changes that are taken into account in the simulation are hereafter referred to as CAP Reform 2000/2008. The year 2000 refers to the start of Agenda 2000, when intervention prices in the arable and beef sectors were decreased for the first time. The CAP reform will be completed in 2008 when the milk market reform is fully implemented. Besides changes in intervention prices and direct payments, the effects of partly or fully decoupled direct payments in combination with milk quota abolition are analyzed as well.

From 1998 onwards MINAS standards were gradually tightened, allowing farmers time to adjust. Objective 4 is to analyze the economic and environmental effects, from nutrients from animal manure application standards in 1996 to nutrient loss standards under MINAS and nutrients from animal manure application standards under MAO in 2004. The nutrients and manure policies that will be effective in 2004 are simulated as if they are fully introduced in the base, with exogenous variables at observed base period levels (1996). Results are compared with a base or benchmark. To bridge the long period between the 2004 manure and nutrients policies and manure and nutrients policies in the 1996 base period, some farm management adjustments taken from farm level studies are included exogenously in DRAM. It is assumed that these farm management adjustments are directly induced by the changes in manure and nutrients policies from manure and nutrients policies in the base period (1996) to 2004 measures. A major contribution of this study is that DRAM features endogenous manure prices affecting agricultural production and allocation of inputs under different scenarios.

At present only 30 to 40% of added value created in agribusiness (primary agriculture, agricultural input delivering and output processing industries) comes from primary agriculture (Koole and van Leeuwen, 2001). Bakker (1986) linked the results of DRAM to an input-output (IO) model for economy wide analyses of changes in agriculture. However, he did not fully integrate DRAM and the IO model. In this thesis a method will be presented that integrates DRAM with the available IO model. Next, the approach of mixed input-output modeling is used to extend the effects of the policy simulations described in objectives 3 and 4 to the Dutch economy as a whole (Millar and Blair, 1985; Roberts, 1994).

1.5 Outline of the thesis

Chapter 2 provides a general description of DRAM. The general overview concentrates on the different components of the agricultural sector model. Chapter 2 presents in detail the choices concerning regional differentiation and the specification of activities, inputs, outputs and technologies.

Chapter 3 provides a general discussion of model specification and calibration. The discussion of the mathematical model departs from the standard LP model, as this is the base of DRAM. We discuss both the primal LP model as well as the dual LP model. Special attention to the dual version of the model is considered important because it more clearly shows the steering mechanism of the model as the first order conditions of profit maximization are modeled explicitly. Detailed mathematical presentations of the primal and dual versions of DRAM are provided in Appendix A and Appendix B respectively. Chapter 3 also discusses the calibration of DRAM using the approach of PMP. The PMP approach is described in more detail in Appendix D.

Chapter 4 provides insights into the database of DRAM. The base of DRAM is a description of regional agricultural production and input use in the Netherlands in 1996. An important objective of this thesis is to model manure markets, therefore chapter four focuses on manure and nutrients variables. A more general description of the database can be found in Appendix C. Chapter 4 discusses model results concerning regional manure transport and regional manure prices in the base or benchmark. These model results are validated against observed regional manure transport and manure prices in the base period (1996).

The aim of chapter 5 is to apply the model in order to analyze the environmental and economic effects of what is here called CAP Reform 2000/2008. Effects of milk quota abolition and abolition of price support are analyzed as well. Moreover, in chapter 5 a method is presented to integrate DRAM with an input-output (IO) model and to extend the analysis to the Dutch economy as a whole. A mixed IO model is developed (Millar and Blair, 1985; Roberts, 1994) that uses gross output of agriculture and gross output of related output processing industries as exogenous variables.

Chapter 6 shows the economic and environmental effects of MINAS and MAO nutrients losses and application standards (2004), as if they were introduced in the base period (1996) of DRAM.

Chapter 7 provides a general discussion of DRAM and the results obtained in this thesis. Moreover, the main conclusions are drawn and recommendations for further model development will be made.

2. General description of DRAM

2.1 Introduction

The purpose of this chapter is to give an overview of the Dutch Regionalized Agricultural Model (DRAM). The general structure of DRAM shows many similarities with other mathematical programming agricultural sector models; examples are Horner et al. (1992), Jonasson (1996), Umstätter (1999), Heckelei and Britz (1999), Wiborg (2000) and Lehtonen (2001). This chapter starts with a general overview of the model in section 2.2. In subsequent sections region selection (2.3), inputs and outputs (2.4) and technology (2.5) are discussed in more detail.

2.2 General overview

Introduction

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. Figure 2.1 is a schematic presentation of DRAM. In this section we further discuss different components of agricultural sector models: producer behavior, technology description, availability of fixed inputs and markets and their representation in DRAM. The policy environment that is taken into account in DRAM is described in chapter 1 of this thesis.

Farmers' behavior

The core of DRAM, described in the center of figure 2.1, 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.

Technology

To keep model size manageable and because of data limitations at the farm level, DRAM aggregates technologies of individual farms to the regional level. Because of non-linearities at a very dis-aggregated level, the requirements of exact aggregation are that resource availability, technical possibilities and objectives between farms within a region are comparable. Due to these requirements aggregation bias is unavoidable in sector models. It can be argued that the aggregation bias is different for different farms and agricultural activities as some farms and activities are more specialized and homogenous than others.[2]

In DRAM every region is treated as one farm. Every region in DRAM could potentially produce 25 marketable or final outputs (including one byproduct) and 24 intra-sectorally produced inputs, including 16 different types of animal manure from different types of animals, 6 different types of young animals and 2 types of roughage (grass and fodder maize). Intra-sectorally produced inputs are outputs of agricultural activities that are used as an input in DRAM. On the input side DRAM includes 12 variable inputs, including 7 different types of concentrates for different types of animals. Agricultural inputs and outputs are used and produced by agricultural activities. DRAM describes 32 agricultural activities, with technical (input-output) and economic variables and parameters differentiated per region as far as is possible given data limitations.

Regional differentiation of technical coefficients is especially important for crop production because of the differences in soil type per region and the important relationship between soil type and yield. Moreover, milk is produced through nine types of dairy cow activities, with type and region specific input-output coefficients. Producers may switch between the different types of dairy cow activities

[2] A procedure for exact aggregation of individual farm data to the regional level is provided by Önal and McCarl (1991).

(technologies) depending on relative prices and still produce the same quantity of milk.

Regional specific fertilization requirements of the crops can be fulfilled a) by application of nutrients from mineral fertilizer only b) by application of animal manure only c) by application of both mineral fertilizer and animal manure. Technical restrictions on the total application of animal manure per crop are included to take into account limited acceptation of animal manure because of possible effects on product quality, uncertainties about weed seed in animal manure, uncertainties about nutrient concentration, availability of equipment and land compaction if supplementary mineral fertilizer applications are needed.[3]

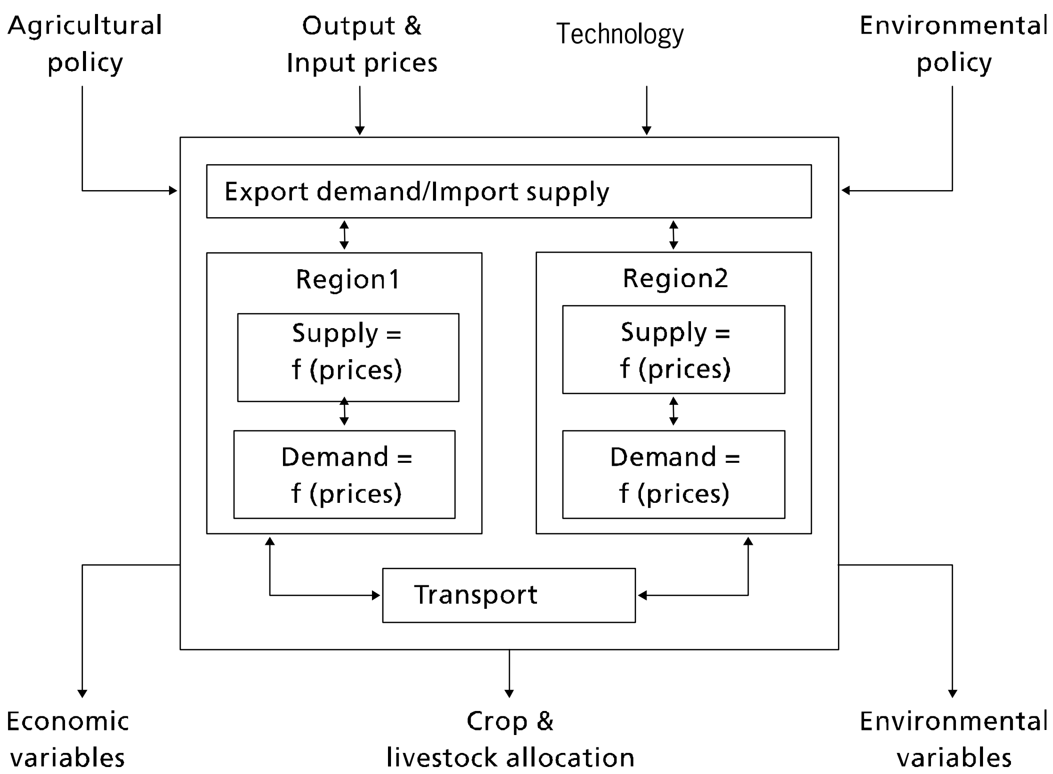

Figure 2.1 Schematic representation of DRAM

[3] See also Feinerman, Bosch and Pease (2004) for a conceptual analysis of manure demand.

Markets

Prices of most outputs and inputs are treated as exogenous variables, as they are assumed to be determined at the internal EU market or world market. For these inputs and outputs the small country assumption is applied: regional prices are fixed. Regional prices are used to take into account possible regional differences in output and input quality, farm size and transport costs.

Intra-sectorally produced inputs in DRAM are different qualities of roughage, young animals and manure. Intra-sectorally produced inputs are produced and consumed within the agricultural sector. Prices of the intra-sectorally produced inputs are partly endogenous within DRAM. Intra-sectorally produced inputs can be traded between regions and internationally. In case intra-sectorally produced inputs are traded between regions, the prices are linked between regions and price differences cannot exceed transport costs (Takayama and Judge, 1971). The small country assumption is also applied to export and import prices: export- and import prices of intra-sectorally produced inputs are fixed. An upper-limit is included for export quantities of animal manure. This is due to great difficulties with respect to the export of animal manure. Large-scale manure processing is also an option to solve the problem of excess manure. Prices of large scale manure processing are different per manure type and are provided exogenously.

Output prices of some arable crops such as consumption potatoes, seed potatoes, marketable crops (e.g. grass seeds) and onions, all vegetable crops and flower bulbs are determined endogenously in the model. For these outputs either the market share of the Netherlands is relatively large or the time between production and consumption is relatively short due to relatively high transport and storage costs. The parameters of the inverse linear demand relationships between prices of outputs and quantities are derived from the neo-classical theory of consumption (see Appendix E).

Fixed inputs

Fixed inputs in the model are land and quotas. Agricultural land and quota for sugar beets are assumed fixed at the regional level. Quotas for milk and starch potatoes are assumed fixed at the national level. Fixed inputs in DRAM are valued by shadow prices on the regional or national balances. The shadow price of a fixed input shows the increase in the objective function as a result of a marginal increase in fixed input. Capital and labor are assumed not to be restrictive at the industry level and they are therefore not included in DRAM.

2.3 Regions

DRAM distinguishes between fourteen regions (figure 2.2). Every region is seen as a regional farm and regions can be regarded as farm sub aggregates. The choice for the regional farm and the selection of regions in DRAM is based on three arguments. The first argument is that the calculation of prices of intra-sectorally produced inputs, especially manure, was of great interest. Manure prices might be different between regions with high livestock densities (sand regions) and regions with relatively low livestock densities. Regional farms can provide better information for this purpose and they are easier to handle than e.g. representative farm types. The second argument is the homogeneity of the soil. Different soil types have different yields and different predominant soil types therefore characterize regions distinguished by DRAM. Besides differences in yields per soil type, environmental impacts can also be soil type specific e.g. intensity of nitrate leaching. Out of the distinguished fourteen regions, seven regions have clay soils, five regions have sand soils and two regions have peat soils.

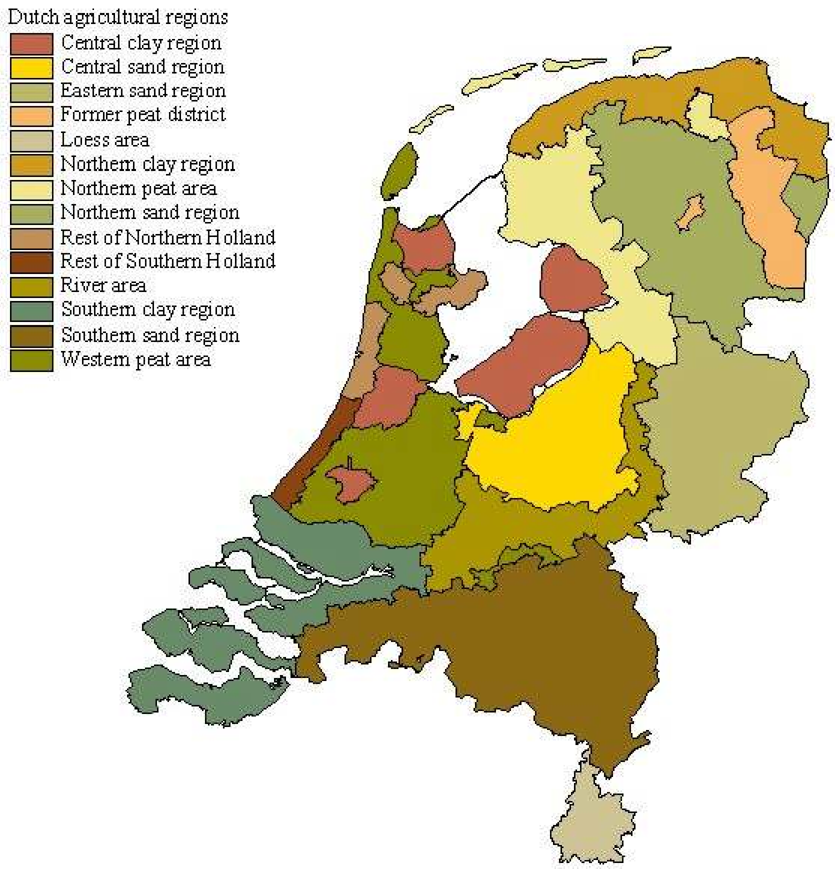

Figure 2.2 Regions distinguished in DRAM

The third argument is the regional concentration of agricultural production in the Netherlands and the related concentration of environmental effects. Intensive livestock, milk and beef production is mainly concentrated in the sand regions in the south, east and middle of the Netherlands. Arable production is concentrated in the clay regions in the north, middle and southwest of the Netherlands. In regions with peat soils, grassland production to feed dairy cows and beef cattle is predominant, while arable production, including fodder maize is almost impossible due to soil characteristics and high groundwater level.

2.4 Inputs and outputs

In DRAM agricultural inputs and outputs are linked to agricultural activities. Economic importance and possible environmental effects determine the selection of agricultural activities and related inputs and outputs.

Within each of the fourteen regions, thirteen arable crop activities (including vegetables in the open and flower bulb activities), two roughage crop activities, one non-food activity, seven intensive livestock activities, including beef cattle and fattening calves, and nine dairy cow activities are distinguished.

Arable crop activities include cereals, legumes, sugar beets, consumption potatoes, seed potatoes, starch potatoes, onions, marketable crops, fodder crops, flower bulbs and three types of vegetables in the open (table 2.1). The forage crop activities are grassland and fodder maize. In this thesis grassland and fodder maize activities in table 2.1 are referred to as remaining grassland and fodder maize activities, excluding hectare of grassland and fodder maize on dairy farms (see section 2.5). Crop activities produce one specific output per activity. This output is sometimes an aggregate (table 2.1).

Table 2.1 Crop activities.

Crop activity	Aggregate of:
Cereals	Wheat, barley, rye, oats, grain maize, spelt
Consumption potatoes	Consumption potatoes
Seed potatoes	Seed potatoes
Starch potatoes	Starch potatoes
Sugar beets	Sugar beets
Fodder crops	Fodder beets, fodder potatoes, fodder cereals, other fodder crops
Marketable crops	Cole seed, caraway seed, flax, grass seed, other marketable crops
Legumes	Green peas, beans, others
Onion	Seed and plant onions, sowing onions, silver onions, other onions
Vegetable crops, extensively grown	Spinach, celeriac, chicory carrot, winter carrot, others
Vegetable crops, intensively grown	Leek, sprouts, strawberry, asparagus, cole, others
Other vegetables	Peas green harvesting, French bean at stem, broad bean
Flower bulbs	All flower bulbs
Fodder maize	Maize silage
Grass	Grass
Non-food	Green manuring, fallow land (also EU regulation), fast growing wood, productive woods, others

Other sectors like horticulture under glass, nursery trees and products produced by these parts of agriculture or horticulture are ignored in the model. In the Netherlands there is limited interaction between these sectors and the modeled agricultural activities.

The livestock activities included in the model represent dairy cows, beef cattle, fattening calves, sows, fattening pigs, laying hens, meat poultry and mother animals of meat poultry. The beef cattle activity is an aggregate of different beef production activities since beef production is not an important activity in the Netherlands. DRAM includes nine dairy cow activities. More detail is included here because of the economic importance and impact of different type of dairy farming on land and manure markets.

Table 2.2 Livestock activities and corresponding outputs (including intra-sectorally produced inputs).

Livestock activity	Outputs
Dairy cows	Milk, beef from dairy cows, calves for replacement of dairy cows, calves for replacement of fattening calves, calves for replacement of beef cattle, grass, maize silage and dairy cow manure
Beef cattle	Beef from beef cattle, calves for replacement of beef cattle, calves for replacement of fattening calves, and beef cattle manure
Fattening calves	Veal and fattening calves' manure
Sows	Piglets, pig meat from sows, and sows' manure
Fattening pigs (20 kg and more)	Pig meat from fattening pigs and fattening pigs' manure
Laying hens (18 weeks and older)	Eggs, poultry meat from laying hens and laying hens' manure
Mother animals of meat poultry (younger than 18 weeks and 18 weeks and older)	Eggs, poultry meat from mother animals and mother animals' manure
Meat poultry	Poultry meat from meat poultry and meat poultry manure

Livestock activities produce more than one output (table 2.2). For example, sows produce meat, piglets and manure from sows. It is assumed that each livestock activity produces a specific type of manure as application costs and transport costs can differ per type of manure. Furthermore, the nutrients content and the workability of nitrogen in animal manure (or mineral fertilizer equivalent) for crop growth, differs per manure type.

The following inputs, other than intra-sectorally produced inputs, are distinguished: concentrates, pesticides, mineral fertilizers (nitrogen and phosphorus) and other variable inputs. Other variable inputs consist of services, other fertilizers, seed and planting materials, energy, hired labor and by-products (as a negative input). Fixed inputs are land available for agricultural production and quotas for milk, sugar beets and starch potatoes.

2.5 Dairy cow activities

In terms of land use, profits and environmental impact, dairy farming is the most important industry in Dutch agriculture. Therefore, DRAM includes nine dairy cow activities characterized by different technologies. The classification of dairy cow activities is based on milk production per dairy cow and use of mineral fertilizer per hectare grassland as the important economic and environmental variables (table 2.3). The necessary data is taken from specialized dairy farms found in the Dutch Farm Accountancy Data Network (FADN).

Table 2.3 Types of dairy cow activities in DRAM

Nitrogen input per hectare grassland	Milk production per dairy cow		
	Low	Medium	High
Low	LMLN	MMLN	HMLN
Medium	LMMN	MMMN	HMMN
High	LMHN	MMHN	HMHN

The procedure is as follows. Specialised dairy farms are classified by milk production per cow and use of mineral fertilizer per hectare of grassland. The total area of grassland and fodder maize, milk production, other outputs, usage of mineral fertilizer and other variable inputs per group of specialized dairy farms is divided by the total number of dairy cows per group of dairy farms. This very specific procedure for example results in a fixed amount of grassland and fodder maize per type of dairy cow in hectare per head. If we multiply the hectare of grassland and fodder maize per dairy cow with the total number of dairy cows, we get the total hectare of grassland and fodder maize on dairy farms. Remaining grassland and fodder maize (table 2.1) are calculated as total hectare of grassland and fodder maize found in the Agricultural Census of Statistics Netherlands (CBS) minus hectare of grassland and fodder maize on dairy farms.

3. Model specification and calibration

3.1 Introduction

DRAM is a non-linear programming (NLP) model with a quadratic objective function and linear restrictions. Given these linear restrictions, DRAM is based on the standard Linear Programming (LP) approach. Therefore, we will briefly discuss the standard LP model in section 3.2 (Paris, 1991). We describe the primal LP model and the dual LP model. The first provides a technology description of how inputs are related to outputs. The dual LP model describes the relationships between input and output prices. The dual LP model more clearly shows the model's steering mechanism as the first order conditions (FOC) of profit maximization are modeled explicitly. In section 3.3 DRAM is presented in the form of a tableau. A full description of the model can be found in Appendix A (primal) and appendix B (dual).

Section 3.4 briefly describes the model's calibration to observed values in the base period using the method of Positive Mathematical Programming (Howitt, 1995a; 1995b; 2002). PMP results into a base or benchmark for agricultural activities, which is very close to observed levels in the base period. The PMP procedure is described in more detail in Appendix D.

3.2 A general primal and dual Linear Programming formulation

In LP literature a problem can be specified from two different points of view (Paris, 1991). The first specification is based on a technology description of how outputs are related to inputs. This specification is referred to as the primal LP problem or primal LP model. The primal LP model assumes that the decision problem of the farmer can be expressed as a problem of profit maximization subject to production technology. The standard primal LP model can be formulated as follows:

$$\text{maximize } Z = \sum_i (p_i x_i - w_i x_i) \qquad (3.1a)$$

$$\text{subject to } \sum_i a_{ik} x_i \le b_k \qquad \forall k \qquad [\pi_k] \qquad (3.1b)$$

$$x_i \ge 0 \qquad \forall i \qquad (3.1c)$$

Where Z is total profit defined as revenue minus variable costs, also the available financial compensation for remaining fixed inputs (capital and labor), p_i is the revenue per unit of activity i, where $i \in S^i$ (set of all activities i), w_i is variable costs per unit of activity i, b_k is total available quantity of fixed input k, where $k \in S^k$ (set of all fixed inputs k), a_{ik} is quantity of fixed input k demanded by activity i, variable x_i is the level of activity i. Restriction (3.1a) maximizes profit from activities. Restriction (3.1b) states that the total use of fixed inputs by activities must be smaller than or equal to the available fixed inputs. Restriction (3.1c) states that all activity levels should be greater than or equal to zero. Variable π_k associated with restriction (3.1b) is defined as the shadow price of fixed input k. The shadow price of a fixed input provides the increase in the objective function if the input could be made less restrictive marginally.

Associated with the primal LP model is the dual LP model. The dual LP model provides insights into how (shadow) prices of inputs are related to (shadow) prices of outputs. As such it helps to understand the economic interpretation of the results of the primal LP model.

The dual LP model is based on the assumption that the decision problem of the farmer can be expressed as a costs minimization problem subject to equilibrium conditions. The dual problem can be derived from the primal problem, provided by restrictions 3.1a to 3.1c, by setting up the Lagrange function and applying the Kuhn-Tucker conditions (Chiang, 1984; Hazell and Norton, 1986; Howitt, 2002). Revenue and costs per unit that appear as coefficients in the objective function of the primal LP model, come back as restrictions in the corresponding dual LP model. The fixed inputs in the primal LP model return as objective function coefficients in the dual LP model. Finally, the direction of the inequalities is reversed in the two problems (Paris, 1991). The dual LP problem is formulated as:

$$\text{minimize } TC = \sum_k b_k \pi_k \qquad (3.2a)$$

$$\text{subject to } \sum_k a_{ik} \pi_k \geq p_i - w_i \qquad \forall i \qquad [x_i] \qquad (3.2b)$$

$$\pi_k \geq 0 \qquad \forall k \qquad (3.2c)$$

Where *TC* is total shadow costs defined as the sum of all input quantities multiplied by their respective shadow prices, π_k is shadow price of fixed input *k*. The value of the objective function of the dual LP model equals the objective function value of the primal LP model 3.1a. The objective function 3.2a of the dual LP model minimizes total shadow costs of fixed inputs. When the shadow price of a fixed input is high, the marginal costs of those products utilizing the fixed input will also be high and this will be an indication that producing those products is less profitable. So the fixed input will be re-allocated to more profitable production activities that use less of the expensive fixed input. Restriction (3.2b) states that marginal costs per activity (MC_i) must be greater than or equal to marginal net revenue per activity (MR_i).[4] Marginal costs (MC_i) is the per unit costs to produce one extra activity *i* and is calculated as the sum of all input requirements per unit of activity multiplied by the (shadow) price per unit of input and summed over all inputs. The marginal revenue is the net revenue of one extra unit of output. Shadow values of restriction (3.2b) provide the activity levels. Restriction (3.2c) states that all shadow prices must be greater than or equal to zero.

3.3 Tableau presentation of DRAM

DRAM is presented in detail in Appendices A (primal version) and B (dual version) respectively. Figure 3.1 presents DRAM as a tableau (Paris, 1991; Berentsen, 1998).

The optimization block of DRAM consists of 15 blocks of restrictions with 2,043 single restrictions. There are 13,889 variables. The number of non-zero elements in the optimization block is 55,518. The number of non-zero elements connected to non-

[4] The general condition for a firm's equilibrium is MC ≥ MR. The alternative, MC < MR, is excluded because in that case a firm can increase its profits by expanding activity numbers or output production (Paris, 1991).

linear variables is 551. A quadratic utility function and quadratic costs functions are causing the non-linearity in DRAM. The relatively large number of variables is mainly explained by the detailed description of the manure markets at the regional level.

The groups of variables (**x**) are shown as columns in figure 3.1. Twelve groups can be distinguished.

- Livestock and crop activities. Livestock and crop activities can both use and produce intra-sectorally produced inputs. Livestock activities both use and produce young animals (calves, piglets, one day chicks). Different kinds of roughage are produced by the crop activities and consumed by livestock activities. Different kinds of animal manure are produced by the livestock activities and consumed by the crop activities.
- Sales of marketable products from agricultural activities;
- Purchase of variable inputs other than mineral fertilizers;
- Purchase of nutrients from mineral fertilizers;
- Application of animal manure produced in animal sheds;
- Production of animal manure in the field by grazing dairy cows;
- Large scale manure processing;
- Exports of different kinds of roughage, young animals and animal manure to the rest of the world;
- Imports of different kinds of roughage, young animals and animal manure from the rest of the world;
- Regional exports of different kinds of young animals and animal manure to other regions within the Netherlands;
- Regional imports of different kinds of roughage, young animals and animal manure from other regions within the Netherlands;
- Production of nutrient surpluses above MINAS threshold levels.

Each activity has its own input-output coefficients. All input-output coefficients together form the matrix **A**. The rows in figure 3.1 indicate the type and form of the restrictions used.

- The regional agricultural product balance states that sale of agricultural products should be less than or equal to the supply of agricultural products from agricultural activities. The restriction that corresponds to the agricultural product balance is restriction A.1 in Appendix A.

- The next restriction equals the variable costs function.
- The next three regional balances simulate supply and demand of intra-sectorally produced inputs in the model. Young animals and animal manure can be transported between regions but also internationally. Roughage cannot be transported between regions because of relatively high transportation costs. The balances for young animals, roughage and animal manure are described as restrictions A.2, A.3 and A.4 in Appendix A.
- The next restriction gives the quantity of animal manure produced in the field by grazing dairy cows. This is described by restriction A.4b in Appendix A.
- The nutrients requirements per crop match the nutrients need with the available workable nutrients from animal manure and mineral fertilizers. The nutrients requirements are described as restriction A.5 in Appendix A.
- Manure acceptation is modeled at the level of activity groups. Per region, 11 activity groups are distinguished: nine groups of dairy cows (corresponding to the nine type of dairy cow activities), one group with all arable crops including vegetables and flower bulbs, and one group containing remaining grassland and fodder maize activities.[5] The manure acceptation restriction per group reflects behavior that can be observed at the farm level, e.g. arable farmers base fertilization on the entire cropping plan instead of individual crops. Manure acceptation might be limited because farmers fear a negative impact of animal manure on product quality and productivity. Moreover, acceptation might be limited because of possible psychological barriers to accept and use animal manure that is not produced on their own farm. Manure acceptation at the level of activity groups is described as restriction A.6a to A.6c in Appendix A.
- A maximum limit on export of animal manure to the rest of the world. This upper limit is included because the export market for animal manure is quite small. The reasons for this are relatively high transport costs and sanitary and

[5] It is assumed that activity groups are capable to represent farm types. To further investigate this, appendix F compares the cropping plan of the average arable farm as found in FADN with the average national cropping plan of the group of arable activities in DRAM.

phyto sanitary requirements. The restrictions on manure exports to the rest of the world are described as restriction A.7 in Appendix A.

- The next two restrictions link the different activities to the available fixed inputs (land and quotas) at national and regional levels. It is assumed that labor and capital are not restrictive at the activity level. Regional land and sugar beet quotas are provided by restriction A.8 and A.9 in Appendix A respectively. National quotas for milk and starch potatoes are provided by restriction A.10 in Appendix A.
- The Dutch manure policy in the base period (1996) is taken into account by restrictions that limit the maximum application of phosphorus from animal manure per activity group and region (see restrictions A.11a to A.11c in Appendix A).
- The Dutch nutrients accounting system, MINAS, includes a nutrients surplus levy if threshold levels are exceeded (Ministry of Agriculture, Nature Management and Fisheries, 2000; 2001). The nutrients surplus presented at the top of figure 3.1 is defined as nutrients surplus above this threshold level. MINAS is modeled as a balance per group of activities that correspond to different farm types (see restriction A.12a to A.12c in Appendix A).
- Besides the MINAS system, an additional obligation to remove nutrients surplus from the farm was introduced in 2002. It means that producers of animal manure without sufficient manure application capacity have to contract capacity directly from landowners or indirectly through a middleman. This system of manure contracts is known as Mest Afzet Overeenkomst (MAO) and is introduced to meet the EU Nitrate Directive (EC/91/676). MAO is modeled as a restriction at the level of activity groups. That means that the total manure application capacity per group depends on the amount of land allocated to the different groups[6] (see restrictions A.13a to A.13c in Appendix A).

The primal NLP model maximizes profit (revenues minus total variable cost) and utility at national level. In DRAM profit is compensation for the use of fixed inputs

[6] Because of different standards for grassland and arable crops under MAO, the total manure application capacity also depends on the allocation of land for grassland and arable crops.

(land, quotas and limited manure export to the rest of the world, see appendix B). Profits per activity are presented in the last row of figure 3.1.

Figure 3.1 *DRAM presented in a tableau*

	Activities														
Constraints	Livestock and crop activities		Sales of marketable products	Purchase of variable inputs, excl. mineral fertilizer	Purchase of mineral fertilizer	Application of animal manure produced in stable	Animal manure produced in field by grazing dairy cows	Large scale manure processing	Export	Import	Regional transport source	Regional transport destination	MINAS nutrient loss		
	produce	use													
Agricultural production	$-a_{ijr}$[1]		1											≤	0
Variable input requirements	a_{ijr}			-1										≤	0
youngstock	$-a_{ijr}$	a_{ijr}							1	−1	1	−1		=	0
roughage	$-a_{ijr}$	a_{ijr}							1	−1				≤	0
animal manure stable	$-a_{ijr}$					1		1	1	−1	1	−1		=	0
animal manure field	$-a_{ijr}$						1							=	0
Fertiliser requirements		a_{ijr}			$-a_{ijr}$	$-a_{ijr}$								≤	0
Acceptation of animal manure		$-a_{ijr}$				a_{ijr}	a_{ijr}							≤	0
Maximum export of manure									1					≤	Export maximum animal manure
Land requirements	1													≤	Available hectares
Quota	a_{ijr}													≤	Available quota
Manure policy in benchmark:															
Fixed amount of phosphor from animal manure		$-a_{ijr}$				a_{ijr}	a_{ijr}							≤	0
Manure policy from 1998 onwards:															
MINAS		$-a_{ijr}$			1	a_{ijr}	a_{ijr}						-1	≤	0
MAO		$-a_{ijr}$				a_{ijr}	a_{ijr}							≤	0
	Direct payment per unit		Market price per unit	Cost per unit	Costs per unit	Animal manure application costs per unit		Costs per unit	Export price per unit	Import price per unit	Transport cost per unit	Transport cost per unit	Levy per unit		

1. a_{ijr} is the technical coefficient that relates activity i to constraint j in region r.

The profit function includes direct payments based on the Common Agricultural Policy of the EU, revenues from sales of agricultural products, the costs of purchased variable inputs, costs of mineral fertilizer, costs of application of animal manure, costs of large scale manure processing, revenue and costs from export and imports of intra-sectorally produced inputs, regional transportation costs of intra-sectorally produced inputs and levies paid for nutrients surpluses above the MINAS threshold levels.

3.4 Calibration

This section contains a general discussion on the calibration of DRAM. Calibration here means that the outcome or solution of DRAM with respect to regional (crop and livestock) activity levels (almost) exactly corresponds with observed regional activity levels in 1996. The model is calibrated using the Positive Mathematical Programming (PMP) approach (Howitt, 1995). This section briefly discusses the PMP approach. A more detailed discussion can be found in Appendix D. Discussions of the standard PMP approach can also be found in Howitt (1995), Heckelei (1997) and Umstätter (1999).

Linear Programming models have the tendency to overspecialize and as a consequence they will not reproduce the observed activity levels. This is extensively discussed in the literature (e.g. Schipper, 1996). Overspecialization occurs because by definition the standard LP model contains a linear objective function and marginal profit is constant. As a result the model will use fixed inputs for the most profitable activities. Overspecialization could be avoided by adding more constraints to the model. However, especially in aggregated models the number of empirically justified restrictions/constraints is relatively small compared to the number of activities (Heckelei, 1997). Moreover, additional constraints will hamper the models' flexibility to react to exogenous shocks.

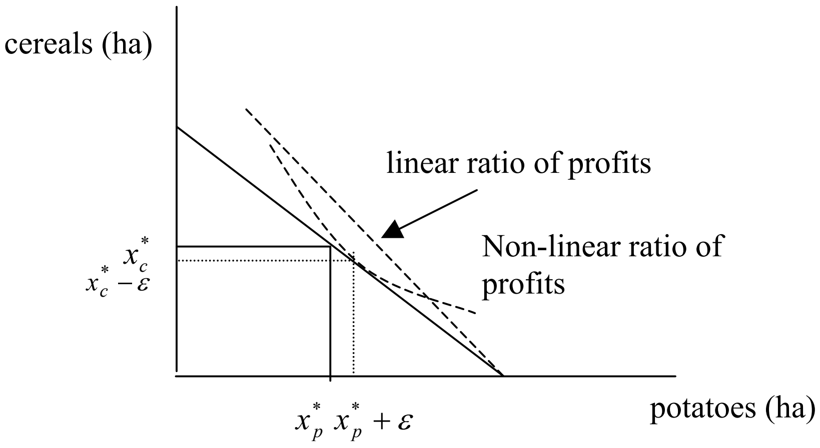

Figure 3.2 The calibration of an LP model to observed activity levels based on the PMP approach

Using the method of PMP, the parameters of a non-linear profit (objective) function can be specified in such a way that the model calibrates almost exactly to the observed activity levels. A graphical example of the allocation of land for cereals and potatoes, as the result of a standard LP model and the PMP model, is provided by figure 3.2. According to figure 3.2 the total amount of land can be allocated to cereals and potatoes. The observed levels of cereals and potatoes are provided by x_c^* and x_p^* respectively. If all the land is used for potatoes the allocation of land to cereals will be zero and vice versa. In an LP model the ratio of individual profits is represented as a straight line (constant marginal profit). Total profit will be at its maximum at the point where the production possibility line and the ratio of individual profits meet. The LP model represented in figure 3.2 provides a cropping plan with 100 percent potatoes; all the land will be allocated to potatoes (overspecialization). Because of technical difficulties this result is not realistic. The PMP model will avoid such an extreme overspecialization. The PMP model starts with the assumption that farmers maximize profits with the observed allocation of land for cereals and potatoes (the only two activities in our example) and technology is constant. If the allocation of land to potatoes increases above the observed level in a base period, this will decrease marginal profitability. This can be explained in terms of yield and revenue as well as costs. Yield and revenue per hectare of potatoes decreases relative to cereals because additional land allocated to potatoes is relatively less suitable for potatoes compared to cereals (Howitt, 1995a). Because of an increased allocation of land to potatoes, marginal costs per hectare will increase as well. Possible reasons could be the increase in pressure from diseases and the resulting increase in pesticide use, as well as an increase in machinery costs due to increased travel distances. As the land allocated to potato gradually increases, the land allocated to cereals will decrease. The effects on marginal profitability of a decrease in land allocated to cereals are the opposite of an increase in land allocated to potatoes. The PMP model translates this process into a non-linear profit function (see figure 3.2). Non-linearity means that marginal profit is not constant but rather a function of the activity level as explained above.

PMP calibrates to observed activity levels in three steps. In the first step the primal LP model (3.1a) to (3.1c) is extended and reformulated as a constrained LP model as follows:

maximize $Z = \sum_i p_i x_i - w_i x_i$ (3.3a)

subject to $\sum_i a_{ik} x_i \leq b_k \quad \forall k \quad [\pi_k]$ (3.3b)

$x_i \leq x_i^* + \varepsilon \quad \forall i \quad [\pi_i^1]$ (3.3c)

$x_i \geq 0 \quad \forall i$ (3.3d)

Where p_i is the revenue per unit of activity i, w_i is the variable costs per unit of activity i, x_i^* is the observed activity level i, ε is a very small positive number, π_k is the shadow price of the fixed inputs, π_i^1 is the shadow price associated with the calibration constraint.

The calibration constraint (3.3c), included in the first step of the PMP approach, states that activity levels cannot exceed observed activity levels in the base year plus a very small perturbation ε (see also figure 3.2). Following Heckelei (1997) the set of activities S^i can be split into a set of 'preferable' activities S^p and a set containing the 'marginal' activity S^m. The perturbation variable ε enables more fixed inputs to be allocated to the preferable activities than are actually observed in the base year, given the input-output coefficient of fixed input k per activity p (a_{pk}). As a result preferable activities are constrained first by the calibration constraint (3.3c). Because more fixed inputs are allocated to preferable activities, fewer fixed inputs (than actually observed) are allocated to the marginal activity as the availability of fixed inputs is restricted by constraint (3.3b). This means that the activity level of the marginal activity will be below the observed activity level and the shadow price of the corresponding activity constraint (3.3c) will be zero, given the input-output coefficient of fixed input k per activity m (a_{mk}). The preferable activities are constrained by the calibration constraint (3.3c). This means that a marginal increase in the availability of fixed inputs only increases the level of the marginal activity. Hence, the shadow price of fixed inputs is determined by the profit of the marginal activity.

Mathematically shadow prices of the fixed input constraint and the calibration constraint can be derived from the Kuhn-Tucker conditions (Chiang, 1984: 722). If we assume that all variables x_i are non-zero and all constraints on fixed inputs are binding, the shadow prices can be formulated as (Heckelei, 1997):

$$\pi_p^1 = p_p - w_p - \sum_k a_{pk} \pi_k \tag{3.4}$$

$$\pi_m^1 = 0 \tag{3.5}$$

$$\pi_k = \sum_m (p_m - w_m)(a_{mk})^{-1} \tag{3.6}$$

Where π_p^1 is the shadow price on the calibration constraint of the preferable activity and π_m^1 is the shadow price on the calibration constraint of the marginal activity. Shadow price π_p^1 provides the contribution to the objective function Z (revenue minus variable costs) if the preferable activity increases marginally. Equation 3.4 shows that the shadow price π_p^1 equals revenue minus variable costs minus the (shadow) costs of the fixed input k per unit. In the literature shadow price π_p^1 is also referred to as unobserved costs (Howitt, 1995). It equals unobserved costs of remaining fixed inputs not included in k.

In the second step of the PMP calibration procedure, total marginal costs per activity are assumed equal to the sum of observed and unobserved costs per activity. By applying the First Order Conditions (FOC) for a competitive equilibrium we can derive the parameters of a non-linear variable costs function (Appendix D). Any type of non-linear costs function with the required properties can be used in principle. Here we use a quadratic costs function that looks as follows: $c(x_i) = kk_i + \alpha_i x_i + 0.5\beta_i x_i^2$. Where kk_i, α_i and β_i are parameters of the costs function to be calculated. According to Heckelei (1997) strong arguments for other functional forms do not exist and the quadratic form has advantages from a computational point of view. The specification of the parameters of the quadratic costs function is further explained in appendix D.

In the third step of the calibration procedure the linear unit costs term, $w_i x_i$, in the objective function 3.3a is replaced by the above-mentioned quadratic total variable costs function: $c(x_i)$. In its standard form the final primal non-linear programming problem can be formulated as:

maximize $Z = \sum_i p_i x_i - kk_i - \alpha_i x_i - 0.5\beta_i x_i^2$ (3.7a)

subject to $\sum_i a_{ik} x_i \le b_k \quad \forall k \quad [\pi_k]$ (3.7b)

$x_i \ge 0 \quad \forall i$ (3.7c)

Note that the calibration constraint (3.3c) has been removed. The model will almost exactly calibrate to the observed activity levels. In figure 3.2 this is represented by the point of contact between the new and non-linear ratio of profits curve and the production possibility line.

4. Data and validation

4.1 Introduction

Mathematical programming models are data intensive. The aim of this chapter is to describe the base or benchmark of DRAM. The base or benchmark of DRAM describes agricultural production, prices and input use in the Netherlands in 1996, the so-called base period. Section 4.2 provides an insight into agricultural activity levels in the base. A more detailed data description of agricultural production in the Netherlands at the regional level can be found in Appendix C. An important requirement of DRAM is to simulate manure market prices and quantities. Section 4.3 discusses exogenous variables playing an important role on manure markets. Section 4.4 discusses endogenous variables such as regional manure transport and manure prices in the base. The latter are outcomes of DRAM and in section 4.4 these outcomes are validated against observed regional manure transport and manure prices in the base period (1996).

4.2 Activity levels

Utilized agricultural area

Table 4.1 provides the utilized agricultural area per region. The Southern sand region is the largest region with about 285 thousand hectares of agricultural land. Some smaller regions, like Rest of South Holland and Rest of North Holland are distinguished because of the relative high share in the regional cropping plan of flower bulbs and vegetables in the open. Table 4.1 shows that the regions with a high share of arable crops are Northern clay region, Central clay region, Southern clay region, Peat colonies and Rest of South Holland. Moreover, table 4.1 shows that regions with a high share of land directly linked to dairy cow activities (see section 2.5 for an explanation) are River area, Northern and Western Peat region, and the sand regions in the north, east, south and middle of the Netherlands. It appears that the River area and the sand regions also have relatively high shares of remaining grassland and fodder maize.

Table 4.1 Utilized agricultural area and land use per region and activity group in base

Region	Area (1000 ha)	Arable crops, vegetables in the open and flower bulbs	Dairy cow activities	Remaining grassland and fodder maize.
		Percentages of total area		
Northern clay region	146.3	55	34	11
Central clay region	129.7	81	16	2
Southern clay region	204.6	82	10	8
River area	119.5	14	63	23
Loess area	31.1	44	35	21
Northern peat area	177.6	4	89	7
Western peat area	190.6	11	80	9
Northern sand region	230.6	24	55	21
Eastern sand region	202.2	8	78	14
Central sand region	76.8	7	70	23
Southern sand region	277.9	30	59	11
Peat colonies	77.2	78	14	7
Rest of North Holland	27.6	40	42	18
Rest of South Holland	6.9	52	36	12
Netherlands	1898.5	34	54	12

Source: CBS, own calculations.

Total agricultural land in the base in DRAM does not seem much compared to total agricultural land reported in 1996 (LEI/CBS, 2002). This difference is explained by agricultural activities that are taken into account. In this study we do not take into account horticulture under glass and nursery trees. Moreover, compared to other studies (Van Staalduinen et al., 2002) we do not take into account very small farms as they are excluded from Agricultural Census. For our purposes it is important that most of the land, effectively used for manure application, is included in DRAM. Moreover, the underestimation of available land is partly compensated for by an underestimation of animal manure production at national level as well (see paragraph 4.3).

Dairy cows

DRAM includes nine types of dairy cow activities, representing nine types of dairy farms taken from the Dutch FADN. The classification is based on milk production per cow and use of nitrogen from mineral fertilizers per hectare grassland. In the base, the average milk production per dairy cow ranges from 5,875 kg per dairy cow activity LMLN to 8,501 kg per dairy cow activity HMHN. Use of nitrogen from mineral fertilizer ranges from 170 kg N per hectare grassland for dairy cow activity LMLN to 394 kg N per hectare grassland for dairy cow activity HMHN. Total nitrogen (N) from animal manure and mineral fertilizers measured as nitrogen from mineral fertilizers equivalents, ranges from 217 kg N per hectare grassland for dairy cow activity LMLN to 507 kg N per hectare grassland for dairy cow activity HMHN.

Table 4.2 shows the distribution of total milk production in the Netherlands for dairy cow activities included in DRAM. Table 4.2 shows that almost 44% of total milk production is produced by low productive dairy cows. Relatively high productive dairy cows produce only about 16 %. Moreover, about 24% of total milk production is produced by dairy cow activities with a low nitrogen input per hectare grassland and about 34% is produced by dairy cow activities with a high nitrogen input per hectare grassland.

Table 4.2 Different types of dairy cow activities classified by milk production (kilogram per dairy cow) and application of nitrogen (N) from mineral fertilizer (kg N per hectare grassland) and total milk production (1000 tonnes) per type of dairy cow activity in1996

	1000 tonnes	%
Milk production (kg per dairy cow)		
LOW	5,017	43.8
MEDIUM	4,612	40.3
HIGH	1,824	15.9
Total	11,453	100.0
Nitrogen from mineral fertilizer (kg N per hectare grassland)		
LOW	2,767	24.2
MEDIUM	4,816	42.0
HIGH	3,870	33.8
Total	11,454	100.0

Milk production (kg per dairy cow): LOW <6500; 6500 < MEDIUM < 7500; HIGH > 7500;
Nitrogen from mineral fertilizer (kg N per hectare grassland): LOW < 250; 250 < MEDIUM < 350; HIGH > 350
Source: LEI, own calculations.

Table 4.3 presents some selected data concerning dairy cow activities. Table 4.3 shows that in 1996 in the Netherlands there are 1.653 million dairy cows. Dairy cows are concentrated in the sand regions (more than 50% of all dairy cows). At the national level, about 50% of the total number of dairy cows is classified as low productive dairy cows (LMLN, LMMN, LMHN). About 13% is classified as high productive dairy cows.

Table 4.3 Characteristics of dairy cow activities in base

Activities	Dairy cows	Grass-land	Fodder maize	Total	Share grassland	Dairy cows per hectare
	(1000 animals)		(1000 ha)		% of total	
LMLN	305	216	21	237	91	1.29
MMLN	91	49	9	59	84	1.56
HMLN	34	16	4	20	78	1.68
LMMN	298	141	28	169	83	1.76
MMMN	309	165	24	189	87	1.64
HMMN	77	39	7	46	86	1.68
LMHN	216	90	23	113	80	1.92
MMHN	219	104	22	126	83	1.74
HMHN	102	45	12	58	79	1.77
Netherlands	1,653	866	151	1017	85	1.63
Sand regions[1]	872	396	117	513	77	1.70
Clay regions[2]	318	174	19	193	90	1.65
Peat regions[3]	463	296	15	311	95	1.49

1. Eastern sand region, Southern sand region, Central sand region, Northern sand region, Peat colonies; 2. Northern clay region, Central clay region, Southern clay region, River area, Loess area, Rest of Northern Holland, Rest of Southern Holland; 3. Northern peat region, Western peat region.
Source: LEI, CBS, own calculations.

Dairy cow activities are modeled with fixed grassland and fodder maize input coefficients (hectare per dairy cow). Table 4.3 shows that the national average number of dairy cows per hectare is especially low for dairy cow activity LMLN. Table 4.3 also shows that the share of grassland in total area of grassland and fodder maize can be quite different per dairy cow activity and region. The share of grassland in total area of grassland plus fodder maize is relatively low in the sand regions. In the peat regions the opposite is true. More data is presented in Appendix C.

Intensive livestock

The total number of intensive livestock activities in the Netherlands, including beef cattle, is presented in table 4.4. Total numbers of animals are based on national statistics. Appendix C shows that a large concentration of intensive livestock activities is found in the Southern sand region. Laying hens and fattening calves are concentrated in the Central sand region.

Table 4.4 Total amount of intensive livestock activities in base

Intensive livestock activity	Number of animals (*1000)
Beef cattle[1]	450
Fattening calves	620
Sows	1,268
Fattening pigs	6,966
Laying hens	28,974
Mother animals of meat poultry	7,593
Meat poultry	43,960

1. Livestock units.

Source: LEI, CBS, own calculations.

Crop activities

Table 4.5 shows the national hectares of arable crops, vegetables in the open and flower bulbs and percentages of individual crop activities in the total area of arable crops, vegetables in the open and flower bulbs. Regional cropping plans can be quite different from the national cropping plan. Cereals have a high share, between 30 and 40%, in total arable land, including vegetables in the open and flower bulbs, in the Northern and Southern clay region. High shares for consumption potatoes, about 20%, are found in Central clay region and Southern clay region. Starch potatoes are concentrated in the Peat colonies, with over 40% of arable land allocated to starch potatoes. Table 4.5 also shows the distribution of grassland and fodder maize directly linked to dairy cow activities. From the table it is clear that on average 15% of the hectare of grassland and fodder maize directly linked to dairy cow activities is used as fodder maize and 85% is of this acreage is used as grassland. It can be calculated from table 4.5 that about 33% of the total area of fodder maize belongs to the category of remaining fodder maize. Within the group of remaining grassland and fodder maize activities, about 70% of the land is allocated to grassland.

Table 4.5 Crop production in the Netherlands and percentages in national cropping plan in base

Activities	Level (1000 ha)	%
Arable crops, vegetables in the open and flower bulb activities:		
Cereals	199	31
Consumption potatoes	83	13
Seed potatoes	39	6
Starch potatoes	62	10
Sugar beets	116	18
Fodder crops	7	1
Marketable crops	26	4
Legumes	5	1
Onion	17	3
Vegetable crops, extensively grown	26	4
Vegetable crops, intensively grown	19	3
Other vegetables	11	2
Flower bulbs	19	3
Non-food	17	3
Total arable crops, vegetables in the open and flower bulbs activities	646	100
Dairy cow activities:		
Grassland	866	85
Fodder maize	151	15
Total grassland and fodder maize directly linked to dairy cow activities	1,017	100
Remaining grassland and fodder maize activities:		
Grassland	165	70
Fodder maize	71	30
Total remaining grassland and fodder maize activities	236	100
Total field and crop activities	1,899	100

Source: LEI, CBS, own calculations.

4.3 Manure and nutrients

To simulate manure and nutrients policies, the modeling of manure prices is a central element in DRAM. Manure prices are modeled through regional balances of animal manure demand and supply. Nutrients in animal manure can be used to fulfill fertilization requirements of the crops. The demand price of animal manure is a function of the (shadow) price of nutrients in animal manure, the nutrient content of animal manure, the workability of the nutrients in the manure, manure application costs, manure acceptation, transport costs of animal manure, export and import possibilities, costs of large scale manure processing and manure and nutrients policies (see restrictions B.5a to B.5f, B.6, B.7, B.8 and B.9b in Appendix B). These variables are discussed below. To be clear, manure prices are outcomes of DRAM. They can be validated against observed manure prices in the base period.

Manure and nutrients policy

Manure and nutrients policies in the period 1994-1997 included phosphorus utilization standards from animal manure for field and arable crops (table 4.6). Utilization standards of 1996 are used to calibrate the model.

Table 4.6 Phosphorus utilization standards for animal manure for the period 1994-2000, kg P[1] per hectare.

Year	Grassland	Fodder maize	Arable land
1994	87.34	65.50	54.59
1995	65.50	48.03	48.03
1996	58.95	48.03	48.03
1997	58.95	48.03	48.03
2000	37.12	37.12	37.12

1. 1 kg phosphorus (P) = 2.29 kg phosphate (P_2O_5).

Source: Ministry of Agriculture, Nature Management and Fisheries (1995).

Other measures implemented in the 1994-1997 period were related to a more optimal use of nitrogen in animal feed, the use of low emission housing systems, sealing of manure storage facilities, low emission application of animal manure and large scale processing of animal manure. In DRAM we translate these measures in terms of nutrients excretion per animal, workable nutrients content in animal manure and application costs of manure.

Manure and nutrients excretion

Manure excretion in volume terms depends on the milk production per dairy cow activity. Table 4.7 shows the average manure and nutrients excretion per dairy cow in the base. Data are taken from the Agricultural Census (CBS) in the Netherlands combined with information from IKC-V (1993). Regional manure excretion per dairy cow activity, including calves and heifers ranges from 28.5 m^3 for activities LMLN, LMMN and LMHN in the peat region, to 33.6 and 33.7 m^3 for activities HMLN, HMMN and HMHN in the sand and clay regions respectively. Table 4.7 also shows manure excretion of other animal types. Data are taken directly from the Agricultural Census 1996 (CBS). Regional differences are the result of differences in the composition of an animal activity as specified in DRAM. For example, excretion of laying hens in DRAM includes excretion by laying hens older than 18 weeks and laying hens younger than 18 weeks. Excretion per laying hen younger than 18 weeks differs from excretion per laying hen older than 18 weeks. Hence, average excretion per laying hen is also a function of the share of laying hens younger than 18 weeks and laying hens older than 18 weeks in the total number of laying hens per region.

Table 4.7 shows manure excretion in volume terms per laying hen if the manure is produced in housing systems where it has a low dry matter content. However, in 1996 about 63% of all manure is produced in housing systems where it has a much higher dry matter content (Brouwer, Baltussen and Daatselaar (eds.), 1997). In these housing systems manure excretion in volume terms equals 0.01 m^3 per laying hen younger than 18 weeks and 0.0254 m^3 per laying hen older than 18 weeks (van Eerdt, 1998).

Mandersloot (1992) provides the nutrients (nitrogen (N) and phosphorus (P)) excretion for different types of dairy cows. Nutrients excretion of calves and heifers for the replacement of dairy cows equals 43 kg N and 4.3 kg P per young animal younger than one year, and 89.8 kg N and 9.2 kg P per animal between 1 and 2 years old (Werkgroep Uniformering Berekening Mest- en Mineralencijfers, 1994a). The numbers of calves and heifers per dairy cow activity are taken from FADN. The resulting nutrients excretion per type of dairy cow per region is corrected in such a way that the average nutrients excretion per dairy cow equals figures from the Agricultural Census (CBS, Werkgroep Uniformering Berekening Mest- en

Mineralencijfers, 1994a). The correction factor is constant (in kg per head) for all types of dairy cows. Results are presented in table 4.7 and figure 4.1.

Table 4.7 Manure and nutrients excretion of livestock activities in base.

Livestock activity	Manure (m^3 per animal)	Nutrients (kg per animal)		
		Total N-excretion	N-in manure[1]	P
Dairy cows	30.738	211.4	184.34	22.6
Beef cattle	12.66	91.10	79.44	9.58
Fattening calves	3.84	11.52	9.40	1.88
Sows	5.648	35.91	27.29	7.15
Fattening pigs	1.25	14.30	10.73	2.27
Laying hens	0.072	0.914	0.86	0.21
Mother animals of meat poultry	0.022	1.11	0.87	0.23
Meat poultry	0.011	0.61	0.54	0.092

1. Corrected for the emission of nitrogen as ammonia in animal sheds and during storage.

Source: Mandersloot (1992), Werkgroep Uniformering Berekening Mest- en Mineralencijfers (1994a, 1994b, 1994c), van Eerdt (1998), LEI, CBS, own calculations.

The average regional nitrogen excretion per dairy cow activity is presented in figure 4.1. This figure shows that nitrogen excretion increases with milk production per dairy cow and the use of kg N per hectare grassland. Notice that nitrogen excretion per dairy cow activity differs between the regions. The distribution of phosphorus excretion per dairy cow activity per region follows the distribution of nitrogen excretion per dairy cow activity per region.

In DRAM we assume that part of the manure and nutrients excretion of dairy cow activities occur in the field during pasturing (Mandersloot, 1992). With respect to other animal activities it is assumed that all manure is produced in animal sheds. Furthermore, it is also taken into account that part of the nitrogen in animal manure produced in animal sheds and other facilities is lost as ammonia into the air. As a result the amount of nitrogen in animal manure is different compared to the nitrogen in total animal manure (table 4.7). Different nitrogen emission percentages are used per animal type, but possible regional differences are neglected.

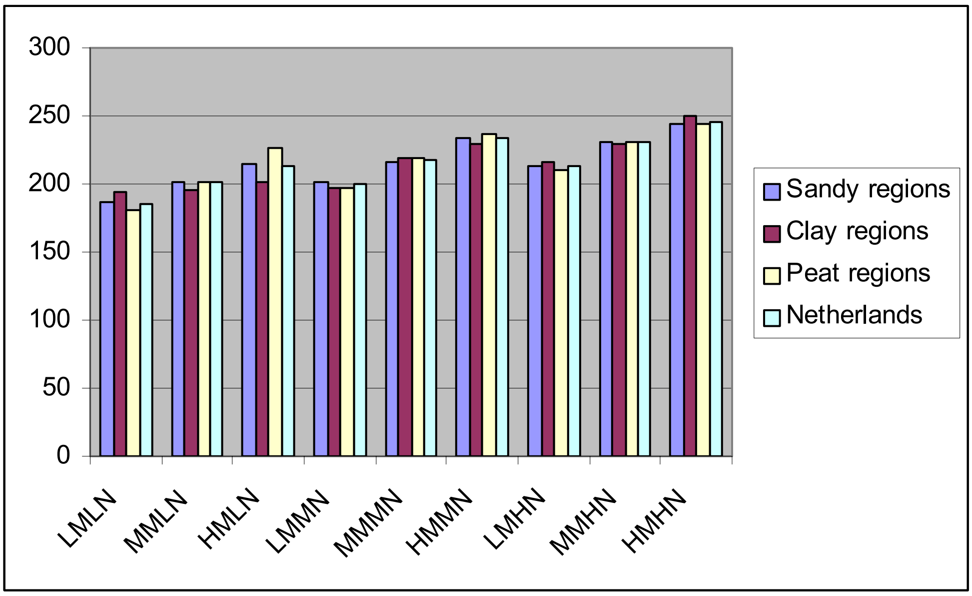

Figure 4.1 Average regional total excretion of nitrogen (kg N per dairy cow) in base

Table 4.8 contains total manure and nutrients excretion in the base of DRAM. Dairy cows have the highest share in total manure and nutrients excretion. Compared to results found in the literature DRAM accounts for about 94% of total nitrogen (N) excretion from total manure in the Netherlands and for about 96% of total manure and phosphorus (P) excretion (Brouwer and van Bruchem, 1999).

Table 4.8 Total nutrients excretion from livestock activities in base

	Manure (million m^3)	Nutrients (million kg)		
		N-total manure	N-in manure	P
Dairy cows	50.8	349.3	319.0	37.32
Beef cattle	5.7	41.0	35.8	4.32
Fattening calves	2.4	7.1	5.8	1.17
Pigs	15.9	145.2	109.3	24.88
Poultry	1.9	61.8	55.3	11.87
Total	76.7	604.4	525.2	79.56

Source: CBS, own calculations.

Workable nutrients in animal manure

Workable nutrients in animal manure are defined as the amount of nutrients in animal manure in mineral fertilizer equivalents. For phosphorus it is assumed that 1 kg P from animal manure is equal to 1 kg P from mineral fertilizers. For nitrogen this is different. Nitrogen in animal manure is made up of organic and mineral nitrogen (see e.g. Van Staalduinen et al., 2001: 128). The workable nitrogen in animal manure (after emission of nitrogen as ammonia in animal sheds and other facilities) differs for organic and mineral nitrogen. Furthermore, the workability coefficient differs per crop and time of application (before or after the growing season) (Van Staalduinen et al., 2001: 129). If all this is taken into account, workability coefficients of nitrogen indicate that about 60% of the total nitrogen in animal manure applied to grassland is effective.[7] Regional differences are small because manure is applied to grassland before or during the growing season in all regions. Regional differences in workability coefficients of nitrogen are large when animal manure is applied to arable crops. This is due to the fact that in the clay and peat regions most manure is applied to arable crops after the growing season. In the sand regions animal manure is applied to arable crops before the growing season (Van Staalduinen et al., 2001:128). The workability coefficient of nitrogen in animal manure applied to arable crops indicates that about 75% is workable in the sand regions and about 36.5% in the clay and peat regions.

Application costs of animal manure

Application costs of manure differ per type of manure. Moreover, some differentiation per field or crop activity and per region is taken into account as well. The application costs are presented in table 4.9. The regional differences in costs of low emission application on grassland are caused by differences in equipment. In 1996 low emission techniques were required on grassland in sand-, peat-, and loess regions only.

[7] With respect to manure that is produced by dairy cows in the field, a workability coefficient of zero is assumed. This can be mainly explained by the unequal distribution across the field.

Table 4.9 Costs of manure application in base, € per m³.

Manure type	Land use	Technique	Sand Regions	Clay Regions	Peat Regions
Poultry	Arable land	Standard	3.17	3.17	3.17
		Emission low[1]	4.52	4.52	4.52
Other animals	Arable land	Standard	2.49	2.49	2.49
	Grassland	Standard	2.49	2.49	2.49
	Arable land	Emission low	4.52	4.52	4.52
	Grassland	Emission low	3.39	2.26	2.26

1. After spreading the manure is immediately ploughed under the soil surface.

Source: Oudendag and Luesink, 1997.

Transport costs

Transport costs of animal manure between regions is based on costs per km per unit multiplied by the distances between regions and between centers within regions. Distances between regional centers and within regions are taken from Bakker (1985). The transport costs of animal manure consist of variable costs per km and fixed costs for loading and unloading animal manure (Luesink, 1993).

Manure acceptation

The limited use of animal manure on arable crops is explained by negative effects of animal manure on the quality of arable crops, uncertainties concerning the workability of nutrients in animal manure and management problems such as accommodating the cropping plan and activities on the farm (Baltussen, et al., 1993). In order to take this into account and to avoid unrealistic acceptation and application of animal manure, DRAM includes upper limits on the use of animal manure for arable crops. Data are based on observed behavior as found in the Dutch FADN, presented here in table 4.10. The data shows large differences per crop and per region. There is a positive relationship between the use of animal manure per crop and manure concentration in a region. Luesink (2001) also reports this relationship. The application of animal manure to arable crops is relatively high in the sand regions.

Table 4.10 Application of animal manure to arable crops in base, kg N per hectare

Activity	Sand regions	Clay regions	Peat regions	Netherlands
Cereals	39	8	12	17
Consumption potatoes	123	105	94	109
Starch potatoes	75	91	133	77
Sugar beets	127	38	20	71
Vegetables, flower bulbs	73	40	53	50
Other crops	14	25	21	22

Source: LEI, own calculations.

Restrictions on maximum manure acceptation in DRAM are included per group of activities. It is assumed that restrictions over activity groups better represent actual behavior on different types of farms. The average maximum manure acceptation per group is presented in table 4.11

Table 4.11 Average maximum acceptation of animal manure per activity group in base

	Dairy cows	Arable crops, vegetables in the open and flower bulbs	Remaining grassland and fodder maize
	Kg N/head	Kg N/hectare	
Sand regions[1]	282	145	480
Peat regions[2]	198	125	377
Remaining regions[3]	223	102	381
Netherlands	239	110	413

1. Eastern sand region, Southern sand region, Central sand region; 2. Northern peat region, Western peat region; 3. Northern clay region, Northern sand region, Central clay region, Southern clay region, River area, Loess area, Peat colonies, Rest of Northern Holland, Rest of Southern Holland.
Source: LEI, own calculations.

Table 4.11 requires some elaboration. Table 4.11 contains the regional and national average maximum acceptation of animal manure by dairy cow activities (kg nitrogen (N) from animal manure per head). The average own nitrogen (N) production (kg N in manure per head) equals about 184 kg N. This means that the national average maximum acceptation exceeds the national average of own nitrogen (N) production by about 55 kg N per head. This quantity is potentially available for manure from other types of animals.

Regional maximum manure acceptations on arable crops are derived from observed nutrients surpluses on arable farms at the regional level (De Hoop ed., 2002). The higher the observed nutrient surplus per arable farm per region, the higher the maximum animal manure acceptation per group of all arable crops, vegetables in the open and flower bulb activities. It is assumed that maximum manure acceptation is relatively high on remaining grassland and fodder maize activities, especially in regions with high livestock densities. The procedure is as follows. A certain percentage of the difference between own manure production per hectare and the manure application standard prescribed by manure policies in 1996, can be used by import of manure from other sources.[8] These percentages are different per region and differ from 25 percent in regions with low livestock densities to 95 percent in regions with high livestock densities. This means that in regions with high livestock densities the maximum acceptation of animal manure on remaining grassland and fodder maize is about equal to the manure application standard in the base period. Of course, this manure application standard (table 4.6) cannot be exceeded.

Exports and processing of animal manure

Export of animal manure in the base is limited to about 0.9 million m^3 (Van Staalduinen, et al., 2002). It is assumed that the export of manure mainly consists of poultry manure.[9] In the base about 1 million m^3 of manure from fattening calves is processed in slurry installations. It is assumed that export prices of poultry manure and processing costs of slurry from fattening calves are about equal to manure prices in the manure exporting regions. A very small difference is necessary to make sure that the export of manure in the base equals the observed export and processing of manure in the base period.

[8] The manure application standards are in terms of phosphorus (P) from animal manure (tabel 4.6). They are translated to nitrogen (N) by multiplying the manure standard per hectare (kg P/ha) with the ratio between nitrogen and phosphorus (kg N from total manure/ kg P) for beef cattle. Own manure production equals the equivalent of 2.5 beef animals per hectare.

[9] The export of 0.9 million m^3 is equivalent to 14.9 million kg N and 3.2 million kg P.

4.4 Validation

Here validation is defined as the models' capability to reproduce observed data. Activity levels are reproduced almost exactly by means of the PMP approach. In this section we focus on the transport of animal manure between regions, prices of animal manure, distribution of animal manure across different activity groups and the resulting gross and net nutrient losses at the surface balance. The surface balance method calculates nutrient losses as the difference between the supply of nutrients from different sources (e.g. animal manure and mineral fertilizer) and the uptake of nutrients with harvested crops. Gross nutrient losses include emission from nitrogen (N) as ammonia, but exclude emission of ammonia in animal sheds and storage. Net nutrient losses exclude emission from nitrogen (N) as ammonia in animal sheds and storage, application and pasturing and mineral fertilizer.

Transport of animal manure

Table 4.12 shows the regional manure transport, including transport to other regions, manure exports and manure processing in the base as calculated by DRAM. Compared to the total manure production (table 4.8), transport of manure and manure processing in the base is rather limited, about 9%. This can be explained by the aggregation of DRAM to 14 regions (transport within a region is not included). The transport of manure between individual farms and within smaller regions is not accounted for, but this is mainly transport over short distances at relatively low costs. Because of the regional aggregation of DRAM a comparison of the results with other sources is difficult. Nevertheless it can be stated that transport quantities are in line with results found in the literature (Brouwer, Daatselaar, Welten and Wijnands (eds.), 1996). Source and destination regions are also similar to the regions mentioned in the literature.

Table 4.12 Manure transport per manure type per region, including manure export and manure processing (million m^3)

Manure type	Eastern sand region	Central sand region	Southern sand region	Total
Fattening calves	0	0.44	0.56	1.00
Pigs	0.28	0.22	3.86	4.36
Poultry	0.20	0.31	0.90	1.41
Total	0.48	1.01	6.04	6.77

Source: DRAM.

Table 4.13 Regional prices of animal manure in base (€/m^3)

	Southern clay region	Eastern sand region	Central sand region	Southern sand region	Remaining regions	Average Netherlands
Dairy cows	-1.9	-2.2	-2.2	-3.1	-0.7	-1.5
Beef cattle	-1.9	-2.2	-2.1	-3.2	-0.1	-1.6
Fattening calves	-1.0	-2.0	-1.7	-3.6	-0.6	-1.9
Sows	-1.1	-4.4	-4.2	-6.2	-0.7	-4.7
Fattening pigs	-1.7	-5.7	-5.5	-8.0	-0.6	-5.9
Laying hens	-2.2	-7.1	-7.1	-11.4	0.1	-7.6
Mother animals of meat poultry	-1.5	-2.4	-2.7	-7.0	4.0	-3.6
Meat poultry	-3.9	-3.2	-3.4	-7.5	5.8	-1.4

Source: DRAM.

Manure prices

Producer prices of animal manure in the base are presented in table 4.13. The average producer price of manure from dairy cows in the base was calculated at € -1.5 per m^3 per dairy cow. However, there are large regional differences as presented in table 4.13. The producer price of manure from dairy cows ranges from € –3.1 per m^3 in the Southern sand region to an average manure price of € -0.7 per m^3 in the remaining regions. The producer price of manure from intensive livestock activities also differs between the regions. In the base the producer price of manure from fattening pigs ranges from €–8.0 per m^3 in the Southern sand region to € -0.6 per m^3 in the remaining regions. Producer prices of animal manure in the Southern clay region are also relatively low. This is explained by the transport of large quantities of manure from the Southern sand region to this region. Hoogeveen et al. (2000) reports producer prices of animal manure for different regions in the Netherlands based on data from FADN. Prices are based on removal costs divided by manure removal in volume terms. In 1995 producer prices of fattening pig manure ranged from € 1.82 to € -6.35, depending on the region. Price indications can also be obtained from the so-called Manure bank. This institution managed the supply and demand of different kinds of manure. In 1993 producer prices of fattening pigs' and laying hens' manure equaled €-7.71 per m^3 and €–8.62 per m^3 respectively in the Southern sand region, whereas producer prices equaled € 1.70 and € 2.04 per m^3 respectively in regions with low livestock densities. This provides confidence that DRAM is able to adequately calculate regional producer prices of animal manure. Differences between calculated and actual regional manure prices are relatively small. These results provide confidence that the model is capable of reproducing observed environmental data as well as activity levels, but it does not guarantee the model's prediction quality when exogenous variables are chocked. In the future a validation test will be necessary to test the predictive quality for the period after the calibration period.

Nutrients surface balance

Tables 4.14 and 4.15 present the nitrogen (N) and phosphorus (P) gross surplus per hectare per activity group in the base respectively. Tables 4.14 and 4.15 show that in the base a total of about 385 million kg N and 26.9 million kg P from mineral fertilizer is used in Dutch agriculture. These quantities correspond to the observed use of mineral fertilizer in Dutch agriculture (LEI/CBS, different years). Table 4.14 and 4.15 show that in the base the 99% of the nitrogen and phosphorus in manure from dairy cows are used by the dairy cow activities. Nitrogen and phosphorus in pig manure is more or less equally distributed over dairy cow activities, arable crops, vegetables in the open and flower bulb activities and remaining grassland and fodder maize activities. About 60% of the nitrogen and phosphorus in poultry manure is applied to arable crops, vegetables in the open and flower bulb activities.

The variation in gross nitrogen (N) surplus per hectare for different types of dairy cows in DRAM is high. The gross nitrogen (N) surplus ranges from 215 kg N per hectare for dairy cow activities with less than 250 kg N from mineral fertilizer per hectare grassland, to about 490 kg N per hectare grassland for dairy cow activities with more than 350 kg N from mineral fertilizer per hectare grassland. For the group of arable crops, vegetables in the open and flower bulb activities the gross nitrogen surplus at the soil balance ranges from about 40 kg N per hectare in the Northern clay area to about 145 kg N in the Southern clay area.

Table 4.14 Use of nitrogen (N) from mineral fertilizer and animal manure per manure type, uptake of nitrogen by crops and gross nitrogen surplus for dairy cows and activity groups.

		Dairy cows	Arable crops, vegetables in the open and flower bulbs	Remaining grassland and fodder maize	Total
Available land	1000 ha	1,016	647	235	1,898
Mineral fertilizers	Million kg N	240	116	30	385
Total animal manure	Million kg N	370	67	74	510
- Dairy cows	Million kg N	317	2	1	319
- Beef cattle	Million kg N	13	0	27	39
- Pigs	Million kg N	38	40	33	109
- Poultry	Million kg N	3	26	14	43
Uptake by crops	Million kg N	242	112	54	408
Gross surplus	Million kg N	367	70	50	487
Gross surplus per ha	Kg N per ha	361	108	211	257

Source: DRAM.

Table 4.15 Use of phosphorus (P) from mineral fertilizer and animal manure per manure type, uptake of phosphorus by crops and gross phosphorus surplus surface balance for dairy cows and activity groups.

		Dairy cows	Arable crops, vegetables in the open and flower bulbs	Remaining grassland and fodder maize	Total
Available land	1000 ha	1,016	647	235	1,898
Mineral fertilizers	Million kg P	8.7	18.1	0.1	26.9
Total animal manure	Million kg P	48.3	15.3	12.8	76.4
- Dairy cows	Million kg P	37.0	0.2	0.1	37.3
- Beef cattle	Million kg P	1.7	0	3.3	5.0
- Pigs	Million kg P	8.9	8.9	7.1	24.9
- Poultry	Million kg P	0.7	6.2	2.4	9.2
Uptake by crops	Million kg P	30.7	19.4	7.1	57.1
Gross surplus	Million kg P	26.2	14	5.8	46.1
Gross surplus per ha	Kg P per ha	25.8	22	24.8	24.3

Source: DRAM.

Nitrogen (N) and phosphorus (P) surplus per hectare per activity group is comparable with data found in the Dutch FADN and in the literature (Brouwer and van Bruchem, 1999; Project 'Telen met toekomst', different years). For dairy cow activities the average gross nitrogen surplus per hectare seems rather high. One problem could be the annual variation in the uptake of nutrients with grass production.[10] This is mainly due to changes in weather. Annual variation is not taken into account by DRAM since yields are normalized over a three-year average. It is nevertheless concluded that the results from DRAM are comparable with other sources.

Ammonia emission and net nutrient surplus at surface balance

Table 4.16 shows the total emission of ammonia from agriculture in the base. Compared to other sources the emission in animal sheds and storage as reported in

[10] Yield variation is not a problem for arable crops as forfaits are used to determine nutrients uptake. For nitrogen, uptake by crops equals 165 kg N per hectare and for phosphorus uptake equals 28.4 kg P per hectare.

table 4.16 seems particularly high (RIVM, 2002). One of the reasons could be the relatively high emission coefficients for pig manure (see also table 4.7). The national net nutrient surplus at surface balance in the base is provided in table 4.17.[11] The calculated surplus seems rather high compared to other sources (RIVM, 2002). Differences in yield, especially for grassland, and differences in total available hectare of agricultural land mainly explain these differences at national level.

Table 4.16 Emission of ammonia from agriculture (million kg NH_3).

Source	NH_3
Animal sheds and storage	96.1
Application and pasturing	76.8
Mineral fertilizer	11.1
Total	184.0

Source: DRAM.

Table 4.17 Net nutrient surplus at surface balance (million kg).

	N	P
Inputs		
- animal manure	604	79.5
- mineral fertilizer	385	26.9
- deposition	75	2.2
- rest	38	3.9
Outputs		
- uptake by crops	408	57.1
- manure export and processing	15	3.2
- emission of nitrogen as ammonia	152	
Net surplus	528	52.2

Source: DRAM.

[11] Total nitrogen application from animal manure in table 4.14 (510 million kg N) plus emission of nitrogen (N) as ammonia from animal housing and storage (79 million kg N) plus export and processing of nitrogen (15 million kg N) equals total nitrogen production from animal manure (604 million kg N) in table 4.8.

5. Effects of EU dairy policy reform for Dutch agriculture and economy[12]

5.1 Introduction

In March 1999 the European Council agreed new reforms of the Common Agricultural Policy (CAP), the so-called Agenda 2000 agreements. Agenda 2000 included further decreases of intervention prices in the dairy, beef, and arable sectors and increases in direct payments to compensate farmers for loss of profit. As part of Agenda 2000 dairy policy reform was to start in the marketing year of 2005/6 and was scheduled for full implementation by 2007/8. A mid-term review was anticipated in 2002 to review the policy reforms. The mid-term review resulted in proposals from the European Commission ranging from no further reforms after the implementation of Agenda 2000 to the abolishment of milk quota in 2006. Moreover, it was proposed to decouple the existing direct payments in the arable and beef industries and the new direct payments in the dairy farming industry from agricultural production (European Commission, 2002). On June 26 2003 the European ministers of agriculture agreed a further reform of the CAP (European Commission, 2003). Here we refer to this new agreement as CAP Reform 2003, which modifies Agenda 2000 with respect to dairy policy and other agricultural policies. The commissions' proposal to decouple the direct payments from production was largely accepted by the European ministers of agriculture.

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[12] This chapter is a revised version of: Helming, J.F.M. and J. Peerlings (2003). Effects of EU dairy policy reform for Dutch agriculture and economy; applying an agricultural programming/mixed input-output model. Contributed Paper Presented at the XXV International Association of Agricultural Economists. Annual meeting, August 16-22, Durban (South Africa). It is the result of a study at LEI BV that was financially supported by the Dutch Ministry of Agriculture, Nature Management and Fisheries (Berkhout et al., 2002). The contents of this chapter is the sole responsibility of Helming and Peerlings and does not in any way represent the views of the Ministry. The authors would like to thank Petra Berkhout, Ton de Kleijn, Cees van Bruchem and Frank van Tongeren, being the co-authors of John Helming of the dairy study at LEI BV. Moreover, the authors would like to thank Ludo Peeters (Limburg University Centre (LUC), Belgium) and Myrna van Leeuwen (LEI BV), for suggestions concerning the Input-Output analyses.

In principle, a fully decoupled direct payment approaches the ideal theoretical case of a lump sum transfer to producers. However, the direct payments will be decoupled and provided under certain conditions, such as maintaining land in good agricultural condition and cross compliance. Moreover, individual countries still have the option to provide direct payments for some activities that are at least partly coupled to production. Examples where this is the case are suckler cows, special premiums for beef cattle and slaughter premiums in the beef and veal sector. Furthermore, as an option for individual countries, it is also possible to link 25% of the direct payments to cereals and other arable crops. Moreover, farmers are not allowed to re-allocate land from crops with coupled direct payments in the base period (e.g. cereals) to crops without direct payments in the base period (e.g. potatoes and vegetables). It is uncertain how this restriction will be implemented and enforced. It is therefore not included in our scenario analyses presented below. However, as some crops are excluded from direct payments, a link between direct payments and so-called eligible crops seems unavoidable.

Apart from the practical questions and consequences of the CAP Reform 2003 agreement, there are a number of theoretical questions about the possibility to actually decouple direct payments from production (Jongeneel, 2003). The direct payments, whether they are coupled or decoupled, have an effect on the wealth of the producers and this is likely to affect production. The following potential production enhancing effects are not taken into account in DRAM (Jongeneel, 2003):

- The guaranteed profit stream resulting from decoupled direct payments may make farmers more willing to undertake riskier strategies and plan for associated different crop mixes[13];
- Increased profits make it easier for farmers to invest in their farm operations, particularly when there are liquidity and debt constraints;
- It could be easier for farmers to obtain loans from lenders because of a guaranteed profit and associated lower default-risks. This may affect agricultural investment decisions.
- Farmers could expect policymakers to be inconsistent, i.e. after

[13] Roch and McQuinn (2004) analyze this question. They demonstrate that theoretically decoupling will induce farmers who choose to produce to allocate more land to riskier products than previously.

a certain period the decoupled system might change again to a coupled system. With this in mind farmers might use the decoupled direct payments to invest in the expansion of production capacity to improve their long-term earnings.

Another important issue that was high on the agricultural policy agenda during the mid-term review discussion of 2002 was the continuation or abolition of the milk quota system. Milk quotas were introduced in the EU in 1984 to overcome the problem of growing milk surpluses and budget costs. In the CAP Reform 2003 agreement the milk quota system has been extended until 2014/15. Given the ongoing discussions to abolish milk quotas, it is interesting to analyze the possible effects of milk quota abolition in combination with decoupled direct payments in the dairy sector.

In the Netherlands quota abolition would probably lead to an increase in milk production, an increase in demand for land to produce feed for an increased number of dairy cows, and an increase in the production of manure and nutrients (Phosphate (P_2O_5) and Nitrogen (N)). As a result, quota abolition would affect not only dairy farming but other agricultural industries as well, since in the Netherlands agricultural industries are interlinked through land and manure markets. The link with manure markets results from stringent nutrients and manure policies in the Netherlands. Basically these policies limit the total amount of nutrients from animal manure and mineral fertilizers that can be applied to the land.

Moreover, quota abolition would affect not only dairy farming and other primary agricultural industries but also agricultural input delivering and output processing industries. At present only 30 to 40% of profits created in agribusiness (primary agriculture, agricultural input delivering and output processing industries) comes from primary agriculture (Koole and van Leeuwen, 2001). At the industry level and for the economy as a whole the economic and environmental effects of milk quota abolition are complex. Models help to quantify these effects.

The aim of this chapter is twofold. The first aim is to analyze the ceteris paribus environmental and economic effects of what we call CAP Reform 2000/2008 in combination with partly or fully decoupled direct payments and milk quota abolition for Dutch agriculture.[14] The second aim of this chapter is to present a method to integrate DRAM with an input-output (IO) model and to extend the analysis to the Dutch economy as a whole. A mixed IO model is developed (Millar and Blair, 1985; Roberts, 1994) that uses gross output of agriculture and related output processing industries as exogenous variables.

The chapter is organized as follows. Section 5.2 presents the methodology behind the mixed IO model and its integration with DRAM. In section 5.3 DRAM and the mixed IO model are applied to analyze the effects of different scenarios. Section 5.4 contains sensitivity analyses of the results in relation to the abolition of the milk quota system. The chapter concludes with discussion and conclusions.

5.2 The mixed input-output model

In this section we present a method to include results from the programming model in a mixed IO model. The usual format of the standard demand-side IO model is $(\boldsymbol{I}-\boldsymbol{A})\boldsymbol{X}=\boldsymbol{D}$ and $\boldsymbol{X}=(\boldsymbol{I}-\boldsymbol{A})^{-1}\boldsymbol{D}$, where $\boldsymbol{I}$ gives the unity matrix. The final demand elements, **D**, and the matrix of IO coefficients, **A**, are considered exogenous. **X** is the matrix of gross output. Changes in final demand of industry *i* (D_i) are exogenous to the model and it is the effects of these changes on industrial gross outputs, X_i's, that are quantified through the IO model (Millar and Blair, 1985).

It is also possible to employ a mixed IO model, in which final demands for some industries and gross outputs for the remaining industries are specified exogenously. Here, a mixed IO model (Millar and Blair, 1985; Roberts, 1994) is applied that uses gross output of agriculture and gross output of output processing industries as exogenous variables.

[14] CAP Reform 2000/2008 includes all measures to reform the CAP as mentioned in Agenda 2000 and CAP Reform 2003 (see also chapter 1).

To explain the link between agriculture and the rest of the economy we consider a four-industry model: agriculture (1), output-processing industry (2), agricultural input delivering industry (3) and other industries (4).[15]

Gross output from agriculture (X_1) is an exogenous variable in the mixed IO model and taken from DRAM. Agricultural output is divided proportionally across the different demand categories on the basis of the shares in the original IO table. This provides the transaction from agriculture to the output processing industry (X_{12}). The exogenous gross output of the output processing industry can now be calculated as:

$X_2 = X_{12} / a_{12}$ Where X_2 denotes the gross output of the output processing industry and a_{12} the IO coefficient between agriculture and output processing industry. The transaction from the input delivering industry to agriculture (X_{31}) is taken from DRAM. Next, the IO coefficient describing transactions from the agricultural input delivering industry to agriculture (a_{31}) can be recalculated: $a_{31} = X_{31} / X_1$.

To close the mixed IO model, final demand from the agricultural input delivering industry (D_3) and other industries (D_4) is assumed exogenous. So, endogenous variables in the mixed IO model are gross output of the agricultural input delivering industry (X_3), other industries (X_4) and final demand of agriculture (D_1) and the output processing industry (D_2).

With X_1, X_2, D_3 and D_4 as the exogenous variables on the right hand side and endogenous variables X_3, X_4, D_1 and D_2 on the left, the basic IO relationships can be noted as (exogenous variables are indicated using an over bar):

$$\begin{bmatrix} -a_{13} & -a_{14} & -1 & 0 \\ -a_{23} & -a_{24} & 0 & -1 \\ 1-a_{33} & -a_{34} & 0 & 0 \\ -a_{43} & 1-a_{44} & 0 & 0 \end{bmatrix} \begin{bmatrix} X_3 \\ X_4 \\ D_1 \\ D_2 \end{bmatrix} = \begin{bmatrix} -(1-a_{11}) & a_{12} & 0 & 0 \\ a_{21} & -(1-a_{22}) & 0 & 0 \\ a_{31} & a_{32} & 1 & 0 \\ a_{41} & a_{42} & 0 & 1 \end{bmatrix} \begin{bmatrix} \overline{X_1} \\ \overline{X_2} \\ \overline{D_3} \\ \overline{D_4} \end{bmatrix} \tag{1}$$

The procedure described above has been applied to the model used in this paper. Given the different levels of aggregation in DRAM and the mixed IO model a data

[15] To explain the method it is assumed here that all industries belong to one of the 4 categories. In reality a particular industry can be both output processing and input delivering.

harmonization procedure had to be applied. This procedure is included in Appendix G.

The DRAM/IO system described above provides a simple way of calculating economy wide effects of dairy policy reform. However, the assumptions underlying the programming and IO models also apply here. Thus there are fixed IO coefficients (except for transactions between agriculture and agricultural input delivering industries), the supply of factor inputs is perfectly elastic (except for land and quotas which are fixed for agriculture) and there is no explicit link between profits and final demand (Millar and Blair, 1985).

5.3 Policy simulations and results

Policy simulations

The exact measures included in what is here referred to as CAP Reform 2000/2008 are presented in Appendix 5.1. There is a lot of uncertainty as to what degree direct payments can or will be decoupled from agricultural production. Therefore the economic and environmental effects of the CAP Reform 2000/2008 are analyzed according to different degrees of decoupled direct payments. The following scenarios will be analyzed:

1. Scenario S1 is a simulation of CAP Reform 2000/2008 (see Appendix 5.1) as if it is fully introduced in the base, with exogenous variables at base period values (1996). It is assumed that the national milk price will decrease by 15%. The milk quota will increase by 1.5%. All direct payments are coupled to production.
2. Scenario S2 simulates CAP Reform 2000/2008 with direct payments 50% decoupled from agricultural production. The part of the direct payment that is decoupled from production is added to industries revenues ex-post.
3. Scenario S3 simulates CAP Reform 2000/2008 with fully decoupled direct payments. This simulates the ideal scenario of a lump sum transfer to producers, since the direct payment is simply removed from the model's objective function. The decoupled direct payments per activity, equal to their levels in scenario S1, are added to industries revenues ex-post.
4. Scenario S4 is equal to scenario S3, except for milk quota abolishment and a

decrease in milk price by 30%. This percentage is assumed to be the difference between the national milk market price in the base and the world market milk price after abolition of the milk quota system in the EU.

The benchmark or base is a simulation of Dutch agriculture in the base period with agricultural activity levels calibrated to observed figures in 1996 and manure policies as described in chapter 4 (table 4.6).

Results

Agricultural production

Results with respect to the number of animals are presented in table 5.1. The number of dairy cows increases slightly in S1 as a result of the increase of 1.5% in the milk quota. Due to lower prices for beef under CAP Reform 2000/2008, the number of beef cattle decreases by about 9%. The increase in the number of meat calves (+20%) is explained by the introduction of the slaughter premium, while the market price of veal is assumed constant.[16] Under S2 the number of meat calves and beef cattle decreases as compared to S1. This is to be expected because direct payments are 50% decoupled from production and production is determined more by market prices. The decrease in the number of beef cattle and meat calves will result in a decrease in manure and nutrients production. Manure prices go down as manure markets are less restrictive, and as a result the number of pigs and poultry goes up slightly compared to S1. In scenario S3, when the direct payment is fully decoupled from agricultural production, the effects of S2 are strengthened. The rather limited effect of changes in manure markets on pigs and poultry production, reflects the relative low share of manure prices in total production costs of pigs and poultry in the base period 1996.

[16] Actual figures for the period 1996-2001 show that veal prices are quite stable, while prices of beef from beef cattle have decreased by 20%.

Table 5.1 Percentage change in livestock numbers and land use in different scenarios (base in 1000 animals or 1000 hectares)

	Base	S1	S2	S3	S4
Cows	1653	1	1	1	25
Beef cattle[1]	449	-9	-44	-60	-88
Meat calves	620	20	14	0	-1
Sows	1268	0	0	0	-2
Pigs	6965	0	1	1	-4
Poultry	90,104	0	0	1	-4
Grassland	1030	1	4	8	14
Fodder maize	221	3	0	-3	-1
Cereals	199	-8	-18	-32	-55
Other crops	448	-1	-1	-2	-7

1. In Livestock Units.

As expected the number of dairy cows increases after milk quota abolition under scenario S4. At the national level the number of dairy cows increases by about 25% while the total milk supply in the Netherlands increases by about 27% (see table 5.2). The increase in the number of dairy cows results in a higher production of manure and nutrients and higher prices for animal manure. This in turn leads to a decrease in production in other livestock industries. These results show that dairy cow activities are very competitive on national manure markets after the abolition of milk quota.

Table 5.1 also shows the effects on crop activities. Under S1 land allocated to cereals decreases by about 8% compared to the base. This can be explained by lower prices under the CAP Reform 2000/2008 which are not fully compensated for by increased direct payments. Decoupling of direct payments decreases profits of formerly supported crops (cereals, fodder maize) relatively to other crops. Under S2 and S3 land allocated to cereals decreases with 18 and 32% respectively. The effect of decoupled payments on fodder maize area is rather limited. This is due to the fact that a large part of fodder maize production in the Netherlands is directly linked to milk production. Under scenarios S2 and S3 most of the land used for cereals is switched to grassland.

After abolition of the milk quota system, scenario S4, the area of cereals decreases by more than 50% and the area of other crops decreases by about 7%, mainly due to a decrease in fallow land and starch potatoes. At the same time the area of grassland increases by about 14%.

Regional effects

The regional effects on agricultural production can be quite different from the national average. In scenario S1, the increase in the number of dairy cows ranges from about +5% in the Central clay region and the Southern clay region to +1% in the sand regions in the south, middle and east of the Netherlands. Under scenarios S2, S3, and S4 this trend with respect to the number of dairy cows is consolidated. In combination with the effect on the number of dairy cows, the effects of the different scenarios on areas of grassland and fodder maize are also largest in the clay regions. For example, the effect on areas of grassland under S2 (partly decoupled direct payments), ranges from +19% in the Southern clay region to +1% in the Peat regions and +3% in the Southern, Central and Eastern sand regions. The relative effect on allocation of land to cereals is exactly the opposite. The decrease in areas of cereals is relatively large in the above-mentioned sand regions, about –30% under scenario S2, and relatively small in the clay regions, about –12% in the Southern and Central clay regions. The relative large decrease of land allocated to cereals in the sand regions results from the relative low yield per hectare and low profitability of cereals in these regions.

Under scenario S1, the sand and peat regions are less competitive in milk production, while the remaining regions are more competitive, i.e. the increases in milk production in the sand and peat regions are below the national increase in milk production. This is shown in table 5.2. Under S3 the sand regions might increase their milk production above the national average. This can be explained by lower prices of animal manure related to the decrease in the number of beef cattle under scenario S3 and the availability of roughage due to the re-allocation of land, particularly from cereals to grassland and fodder maize.

Table 5.2 Percentage change in regional milk supply under different scenarios (base in 1000 tonnes)

	Base	S1	S2	S3	S4
Sand[1]	4,429	0.8	1.0	2.2	24.6
Peat[2]	3,189	1.2	0.8	1.2	14.8
Remaining regions[3]	3,832	2.6	2.7	0.9	38.7
Total	11,451	1.5	1.5	1.5	26.6

1. Eastern sand region, Southern sand region, Central sand region; 2. Northern peat region, Western peat region; 3. Northern clay region, Northern sand region, Central clay region, Southern clay region, River area, Loess area, Peat colonies, Rest of Northern Holland, Rest of Southern Holland.

After the abolition of milk quotas, the milk supply in the Netherlands increases by almost 27% in the short to medium term (see table 5.2). The relative increase in milk production is largest in the remaining regions, especially the clay regions, i.e. about +39%. This is explained by the relatively low livestock density in the base and large-scale land re-allocation of particularly cereals to grassland and fodder maize.

Technology switch in milk production

DRAM distinguishes nine types of dairy cow activities representing different technologies used in dairy farming. Table 5.3 shows the distribution of the milk production in the base over different groups of dairy cow activities. Under S1 there is a limited shift in milk production towards highly productive dairy cows and high use of nitrogen (N) from mineral fertilizer per hectare grassland. This can be explained by considering milk quota as an input for milk production. The lower milk price under S1 directly decreases the shadow price of milk quota in DRAM. Relatively speaking, the latter increases the competitiveness of intensive production methods due to a more intensive use of milk quota per dairy cow and per hectare.

Table 5.3 shows that the decoupling of direct payments, scenarios S2 and S3, increases the competitiveness of dairy cow activities with low nitrogen (N) use per hectare grassland (extensive production methods). This can be explained by the lower shadow prices of agricultural land. Extensive dairy farming systems gain relatively more from this price effect because they use more land per dairy cow. Under scenario S4, abolition of the milk quota system and a milk price support, the shadow price of the milk quota is equal to zero, while the shadow price of land increases compared to the base. All types of dairy cow activities will increase milk production, but as a result of increased land scarcity there is a relative shift towards intensive production methods.

Table 5.3 Percentage change in milk production per type of dairy cow under different scenarios (base in 1000 tonnes)

	Base	S1	S2	S3	S4
Milk production					
(kg per dairy cow)					
LOW	5,024	0.8	1.1	1.1	17.4
MEDIUM	4,619	1.9	1.8	1.9	31.2
HIGH	1,807	2.4	1.8	1.6	40.1
Total	11,451	1.5	1.5	1.5	26.6
Nitrogen from mineral fertilizer					
(Kg N per hectare grassland)					
LOW	2,759	0.9	2.2	2.9	14.0
MEDIUM	4,821	1.5	1.4	1.4	28.6
HIGH	3,871	1.9	1.1	0.5	32.9
Total	11,451	1.5	1.5	1.5	26.6

Milk production (kg per dairy cow): LOW <6500; 6500 < MEDIUM < 7500; HIGH > 7500;
Nitrogen from mineral fertilizer (kg N per hectare grassland): LOW < 250; 250 < MEDIUM < 350; HIGH > 350
Source: DRAM.

Profit

Table 5.4 and table 5.5 show the effects on profits in a number of selected industries and the economy as a whole. Here profit is defined as revenues including coupled or decoupled direct payments minus total variable costs. Table 5.4 shows a relatively strong decrease in profits in dairy farming and beef cattle farming under S1. This can be mainly explained by lower market prices of milk and beef under CAP Reform 2000/2008 which are not fully compensated for by direct payments and other adjustments that are taken into account by the model. Profits in the primary meat calves industry will increase because of the introduction of slaughter premiums and the accompanying increase in production. Profits in the pig and poultry industry are hardly affected. Profit possibilities in arable farming also decrease under CAP Reform

2000/2008, mainly due to the decrease in the market price of cereals and the resulting decrease in the production of cereals.

Table 5.4 Percentage change in profits for primary agricultural industries under different scenarios (base values in million €)

	Base	S1	S2	S3	S4
Dairy farming	2,116	-4.6	-5.0	-5.2	-21.9
Beef cattle	148	-6.1	3.9	23.4	18.5
Meat calves	71	43.8	55.9	54.4	52.3
Intensive livestock farming	972	0.2	0.9	1.7	-5.6
Arable farming, incl. vegetables in the open and flower bulbs	1,417	-2.2	-3.1	-3.6	0.8
Other agriculture	3,190	0.0	0.0	0.1	-0.1
Total agriculture	7,913	-1.3	-1.2	-0.9	-5.6

Direct payments are partly decoupled from production under S2 and fully decoupled from production under S3 and S4. A lump sum payment of half the CAP Reform 2000/2008 direct payment per activity times the activity levels in the base, is included under S2. The remaining half of the direct payment per activity is still linked to agricultural production. Under S3 and S4, the full direct payments per industry are treated as lump sum payments. The calculation bases are crop and animal activity levels in the base period. Profit in the dairy farming industry is about equal under S2 and S3. The small decrease compared to S1 is mainly explained by a decrease in total direct payments[17]. Total direct payments in the dairy farming industry under S2 and S3 are based on (lower) dairy cow numbers in the base. Particularly the primary beef cattle industry gains from a full decoupling of direct payments. This can be explained by the lump sum transfer of direct payments based on (higher) numbers of animals in the base. Moreover, variable costs per unit decreases slightly due to efficiency gains as a result of lower production levels. Profits in the primary meat calves industry appear to be rather stable. This can be explained by the interplay between production levels and decoupled direct payments. Under scenario S1 direct payments are coupled to production and production is relatively high. However, due to increased production, marginal costs per unit are also relatively high. Under S2 and S3 direct payments are

[17] Note that under S2, S3 and S4 direct payments in dairy farming are based on milk production and dairy cow numbers in base.

decoupled. Production is relatively low, but marginal costs per unit are relatively low as well. Profits in the arable industry, for vegetables in the open and in the flower bulb industry are hardly affected by a decoupling of direct payments, at least at the industry level. Scenarios S2 and S3 especially affect the production of marginal crops with a small share in total profits.

Abolition of the milk quota system under S4 clearly decreases profits in the dairy farming industry. This can be mainly explained by the reduction of the milk price to world market levels. In the short to medium term, this cannot be compensated for by increased milk production. Compared to the base, profits decrease by about 22% or about € 460 million. Mainly due to higher manure prices, production and profit possibilities in the rest of the livestock industry also decrease. On the other hand, the higher prices of some outputs and increased profits from manure acceptation increase profit possibilities in the arable industry, for vegetables in the open and in the flower bulb industry.

Table 5.5 shows the effect on profits in some selected industries in the rest of the economy and the economy as a whole. The lower milk price under CAP Reform 2000/2008 also affects profit possibilities in dairy products manufacturing industry (see Appendix H for an explanation of price transmission between industries). S1 has a negative effect on profits in the economy as a whole. The share of agriculture in total profit loss is relatively large under S1, but relatively small under S2 and S3. S2 shows a further decrease of profits in the economy as a whole. This is mainly explained by a decrease in profits in the meat industry and input delivering industries. Full decoupling of direct payments under S3 consolidates the effects of S2. The decrease in profits in the input delivering industries is explained by decreased input use in agriculture.

Table 5.5 Differences in profits from agriculture, agricultural processing and input delivery industries under different scenarios (in million €)

	S1	S2	S3	S4
Total agriculture	-103	-95	-70	-446
Dairy products manufacturing	-103	-103	-103	3
Meat industry	12	-24	-67	-102
Other output processing industries	-29	-28	-29	-60
Agricultural input delivering[1]	58	-14	-107	97
Other industries	4	0	-5	12
Total Netherlands	-161	-264	-382	-496

1. Includes transport of young animals and manure.

Table 5.5 shows that compared to the base, milk quota abolition and a decrease of the milk price by - 30% under scenario S4 will decrease profits in agriculture, while the effect on profits in the dairy products manufacturing industry is about zero. The latter is explained by an increase in gross production in the dairy products manufacturing industry due to increased milk input from the dairy farming industry and lower input costs for raw milk.[18] Under S4 there is a strong decrease in profit possibilities in the meat industry, due to the decreased supply of beef cattle, fattening calves and pigs and poultry. The share of agriculture in total profit loss in the economy as a whole increases due to a more than proportional increase in variable costs in dairy farming. Notice, however, that the DRAM/IO model cannot provide a full welfare analysis because consumer demand and government budget are not explicitly linked to profit generation in DRAM/IO.

Nitrogen surplus

Table 5.6 shows the effects on the nitrogen (N) balance as calculated by the surface balance method. Under S1, the increase in the milk quota and the associated small increase in the number of dairy cows increase the input of nitrogen (N) from animal manure. Moreover, the use of nitrogen from mineral fertilizer increases as well. This can be explained by the re-allocation of land from cereals (relative low nitrogen (N) input crop) to other crops with relatively higher levels of nitrogen (N) input. On the output side there is a decrease in the export of animal manure to other countries. This can be explained by lower domestic manure prices. Both the emission of nitrogen (N)

[18] Note that marginal costs are constant for all industries, except agriculture (see section 5.2).

as ammonia and the nitrogen (N) surplus at the surface balance increase slightly under S1 compared to the base.

Table 5.6 Percentage change of elements of the nitrogen (N) balance (excluding deposition and rest component). Base values in kg N per hectare

	Base	S1	S2	S3	S4
Input					
Animal manure	318	1	-2	-3	8
Mineral fertilizer	203	1	2	2	9
Output					
Uptake by crops	215	0	1	0	3
Manure export	8	-10	-71	-75	0
Emission of nitrogen as ammonia	80	1	-1	-3	4
Net surplus surface balance	219	2	2	1	15

The decoupling of direct payments under S2 and S3 decreases the input of nitrogen from animal manure. Moreover, there is a relative switch towards extensive production methods in dairy farming. From the other hand, the use of nitrogen from mineral fertilizer increases. This is again explained by the re-allocation of land with crops with a relatively low nitrogen (N) input per hectare, to crops with a relatively high nitrogen (N) input per hectare. On the output side there is a decrease in the emission of nitrogen as ammonia and a further decrease in the export of manure. The latter is explained by a further decrease in domestic manure prices, especially because of the decreasing manure supply from the beef cattle industry. The net result of these changes is a small increase in net nitrogen (N) surplus at the surface balance compared to the base.

The number of dairy cows increases after abolition of the milk quota system in scenario S4. This also causes the manure and nutrients supply from dairy cows to increase. Market prices of animal manure increase and as a result the manure supply from other livestock industries decreases. Table 5.6 shows that the net result is a considerable increase in the production of nitrogen from animal manure (+8%). Moreover, the application of nitrogen (N) from mineral fertilizer also increases (+9%). As a result of the increased input of nitrogen (N), both the emission of nitrogen (N) as ammonia and the net nitrogen (N) surplus at the surface balance increases, by +4% and 15% respectively.

Compared to the national average presented in table 5.6, regional effects can differ greatly. Under scenario S4, the largest increase in the emission of nitrogen (N) as ammonia and net nitrogen (N) surplus at the surface balance is found in regions with relatively low emission and surplus levels in the base. The largest increase in the emission of nitrogen (N) as ammonia was found in the Northern clay region (+38%), followed by the Central clay region (+13%). The lowest increase in the emission of nitrogen (N) as ammonia was found in the Eastern, Southern and Central sand region, about +1%. The highest increase in nitrogen (N) surplus at the surface balance was also found in the Northern clay region and the Central clay region, +42% and +21% respectively. The increase in net nitrogen (N) surplus was again lowest in the above-mentioned sand regions, between +7% in the Eastern sand region and +4% in the Southern and Central sand regions. These regional differences are explained by regional differences in base positions.

5.4 Sensitivity analysis

A sensitivity analysis is conducted to explore the effects of the abolition of the milk quota system, S4, with respect to domestic, import and export prices of grass, maize, cereals and other arable crops.[19] These increased by 20% because of the increased feed demand due to increased numbers of dairy cows. Moreover, it is assumed that as a result of these price changes the price of concentrates for all animal activities increases by 10%. Results are summarized in table 5.7. When the above mentioned price changes are taken into account, the increase in the number of dairy cows and milk production compared to the base is limited to 19% and 20% respectively. This was 25% and 27% respectively. The decrease in hectares of cereals is now limited to 32%. The profits in the dairy farming industry decrease by almost 30%, a change of -22% compared to the base. The price increase of concentrates too decreases production and profit possibilities in the intensive livestock industry (pigs and

[19] With the exception of prices of potatoes, marketable crops, vegetables and flower bulbs, which are determined endogenous in the model.

poultry).[20] Table 5.7 shows that environmental effects are smaller compared to the original S4 scenario. Emission of nitrogen (N) as ammonia changes by –2% instead of +4%, while the net nitrogen (N) surplus increases by 10%. This was 15% in the original S4 scenario. These results show that they might be sensitive to values of exogenous variables, especially when scenarios are simulated far removed from the original equilibrium. This points to the importance of sensitivity analyses. However, the conclusion that the dairy farming industry will be very competitive on land and manure markets if the quota system and price support is abolished is not rejected.

[20] The decrease in supply could affect the market price of output from intensive livestock production, especially if the supply at European level is affected. This is not taken into account here.

Table 5.7 Percentage change in some selected variables under S4 and S4 and compared to the base. Base values are given in absolute terms.

	Base	S4	S4 plus 20% increase in price of cereals, grass and maize and 10% increase in price of concentrates
Dairy cows (1000 head)	1653	25	19
Milk supply (1000 tonnes)	11,451	26.6	20.0
Cereals (1000 ha)	199	-55	-32
Profits dairy farming industry (million €)	2,116	-21.9	-29.0
Profits intensive livestock farming (million €)	972	-5.6	-18.5
Profits arable farming, vegetables in the open and flower bulbs (million €)	1,417	0.8	4.9
Emission of ammonia (kg N per ha)	80	4	-2
Net nitrogen surplus (kg N per ha)	219	15	10

5.5 Caveats and conclusions

We start off this section with presenting some caveats. First, CAP Reform 2000/2008 will decrease production of especially beef, veal and cereals throughout Europe. Related upward effects on European market prices that could weaken the effects on production of these commodities are not taken into account in DRAM. As a result effects on production especially under scenarios S2, S3 and S4 should be regarded as maximum effects.

Secondly, it is assumed that all policy changes are implemented in the base. Autonomous developments and tightened manure policies inbetween the base period and the actual moment of implementation of the policy changes are not taken into account. This is done for reasons of simplicity and transparency.[21] Autonomous yield increases in cereals, due to technological developments, could decrease the share of direct payments in the total profits and this could limit the effects of the decoupling of direct payments on cereals production.

[21] The next chapter will analyze the possible economic and environmental effects of tightened national manure policies.

Thirdly, labor and capital are not taken into account. They could become restrictive if production increases, as in S4 for milk.

This chapter aims to analyze the environmental and economic effects of what is called CAP Reform 2000/2008, i.e. the decoupling of direct payments and abolition of the milk quota system, for Dutch agriculture and the economy as a whole. Results show that full introduction of CAP Reform 2000/2008 with partly or fully decoupled direct payments has important effects on production and profit in agriculture. Results differ per industry and region. The decreases in intervention prices affect production and profit possibilities in the beef, dairy and arable sectors. Decoupling of direct payments especially affects production in the beef, meat calves and arable industries. Milk production will switch towards relatively more extensive production methods.

Abolition of milk quota and price support will increase milk production in the Netherlands by about 27%. The increase in milk production is also conditioned by Dutch manure policies. Due to the increase in manure and nutrients supply from dairy cows, market prices of manure increase and this in turn will cause the production of final outputs and manure and nutrients in other livestock industries to decrease. Emission of nitrogen (N) as ammonia and net nitrogen (N) surplus at the soil balance increase after abolition of the milk quota system in the base and after inclusion of manure and nutrients policies in the base (1996). It was found that the environmental effects are very different per region.

Changes in gross output in agriculture are fed into a mixed IO model to calculate economy wide effects of the dairy policy reform. It was found that economy wide effects of scenarios with decoupled direct payments exceed by far the changes in primary agriculture.

Boots and Peerlings (1999) used a micro-econometric farm model to analyze quota abolition. They found a smaller milk production increase (15.7% instead of 27%). This is largely due to the fact that the model applied by Boots and Peerlings can be characterized as a short-term model with production factors such as land and capital fixed at the farm level. Links between agricultural industries are not taken into account. Compared to the model presented by Boots and Peerlings (1999), DRAM is less restrictive. Berentsen (1998) simulated a two-price system by means of a mathematical programming farm model and found an increase in milk production at the farm level between 2.7% and 25.1%, depending on the environmental policies implemented. An important difference with our study is that Berentsen (1998) assumes that the milk price at the margin decreases by 40% instead of 30%. Boots and Peerlings (1999) and Berentsen (1998) do not take into account any links between agricultural industries that could affect manure and land prices.

DRAM can be characterized as a short to medium term model since technology (except in dairy farming) is fixed. In the longer term alternative technologies may become available. Notwithstanding the caveats mentioned in this article, it is believed that the proposed modeling system offers a flexible and consistent tool for policy analysis at the level of the Dutch agricultural industry and economy.

Appendix 5.1 Policy measures of CAP Reform 2000/2008

Arable

- The intervention price for cereals, including fodder maize and starch potatoes decreases by 15%, due to a 7.5% price reduction in the marketing years 2000/2001 and 2001/2002;
- To compensate for profit losses direct payments per hectare are increased. Compensation for cereals, oilseeds, fallow land and fodder maize increases from about € 54 per ton to € 63 per ton;
- For starch potatoes the direct payment to the producer increases, so that 75% of the price reduction is compensated for;
- In the Netherlands, the quota for starch potatoes decreases by 7.6%;
- 75%-100% of direct payments for cereals will be decoupled from production[22];
- 40% of the direct payment for starch potatoes will be decoupled from production. As a consequence 60% of the direct payment is still coupled to the production of starch potatoes.

Dairy

- In the period from 2004/2005 to 2007/2008, the intervention price for skimmed milk powder and butter will be decreased by 15% and 25% respectively. It is assumed that these asymmetric changes will result in a reduction of the producer price of milk in the Netherlands by 15%;
- Direct payment per ton milk, to compensate for the decrease in the milk price consists of a payment from the EU and a national envelope. In 2007 the total direct payment equals €35.5 per ton;
- In the Netherlands the milk quota increases by 1.5%;
- After full implementation of the dairy policy reform, direct payment will be fully decoupled from production.

[22] In this chapter it is assumed that direct payments related to crops or animals are either 50% of fully decoupled from production, with the exception of starch potatoes.

Beef

- In three equal steps, the intervention price for beef products will be decreased by 20%. The price cut will start during the first six months of 2000 and will be finished by the marketing year 2001/2002;
- The special premium for male animals increases to €210 per eligible bull and €150 per eligible steer (paid twice during lifetime). The suckler cow premium increases to €200 per suckler cow;
- The slaughter premium for cattle older than 8 months is € 80 per slaughtered animal. The slaughter premium for slaughtered or exported calves equals €50 per calf. In the Netherlands the slaughter premium for cattle is increased by € 22 per slaughtered animal paid by national envelope;
- National ceilings are introduced for the number of (slaughtered) animals eligible for the special male premium, the suckler cow premium and slaughter premium for cattle and calves;
- Decoupling: full decoupling is possible, but individual countries keep the option to retain headage specific payments for either: i) 100% of slaughter premium; or ii) 100% of suckler cow premium plus 40% of slaughter premium, or iii) 75% of beef special premium.

6. Effects of manure and nutrients policies for Dutch agriculture and economy

6.1 Introduction

Since 1985 the Dutch government has implemented several laws and regulations to prevent the growth of livestock production and to reduce and control manure production and use. Measures in the past include the introduction of manure quotas, restrictions on the relocation of the production of manure (the trading of manure quota from one farm to another is restricted), volume restrictions on the application of animal manure per hectare, low emission applications of animal manure and restrictions on the periods during which manure may be applied. Until 1998 the use of animal manure was restricted by utilization standards measured in phosphorus (P) from animal manure per hectare. From 1998 the so-called nutrients accounting system (MINAS) became compulsory for farms with high livestock densities (more than 2.5 livestock units per hectare). MINAS calculates the input (e.g. by means of the purchase of feed, nutrients from mineral fertilizers and animal manure) and the output of nutrients (e.g. through the sale of milk, meat, cereals and manure) at the farm level. Nutrient surpluses above a certain threshold level are taxed. Threshold levels have been sharpened over time and are different per soil type and crop so as to take into account differences in environmental impact. In 2001 MINAS became compulsory for all farmers including arable farmers and other open-field producers. Moreover, in 2002 an additional obligation to remove the nutrients surplus from the farm was introduced. This obligation meant that producers of animal manure without sufficient manure application capacity will have to contract manure application capacity directly from landowners or indirectly through a middleman. This system of manure contracts, known as Mest Afzet Overeenkomst (MAO), is implemented to meet the EU Nitrate Directive (EC/91/676). Under MAO a farm has to calculate its manure production according to normative excretion figures per animal and the number of animals per farm. In 2003 these normative figures, included in the so-called Fertilizer law, are equal to 85% of the average expected manure and nutrients excretion per animal (Ministry of Agriculture, Nature Management and Fisheries, 2002).[23]

The objective of this chapter is to apply DRAM to analyze the economic and environmental effects at the regional and agricultural industry levels, thereby including nutrients from animal manure application standards in 1996 and MINAS threshold levels and connected nutrients surplus levies combined with the animal manure application standards provided by MAO in 2004. Moreover the mathematical programming model is linked to a mixed input-output model to analyze the economy wide effects of the changes in Dutch agriculture (see Chapter 5 and Appendices G and H).

It is assumed that both the MINAS 2004 threshold levels and related nutrient surplus levies and the manure application standards from MAO are introduced in the base, with exogenous variables at base period (1996) levels. To bridge the rather long period between manure utilization standards in 1996 and manure and nutrients policies in 2004, some farm management adjustments taken from farm level studies are included exogenously in DRAM.[24] It is assumed that these farm management adjustments are directly induced by the changes in manure and nutrients policies. The advantage in this respect is the mathematical programming approach of DRAM. Mathematical programming allows the inclusion of many variables that are part of the generally very detailed farm level studies. It is recognized that in reality it is difficult to distinguish between management adjustments induced by policy changes and autonomous technological changes. Sensitivity analyses are used to investigate the effects of the exogenous farm management adjustments.

A general description of DRAM, including a description of the data, can be found in the first four chapters of this thesis. The mixed input-output model that results from

[23] Interaction between MAO and MINAS might result in 'empty' contracts. Empty contracts occur when farmers comply with MINAS by reducing the nutrients surpluses to or below threshold levels, but not with MAO. As a result they have to contract manure application capacity, even though the MINAS requirements are met.

[24] See de Hoop (2002) for farm management adjustments on different types of dairy farms in the period 1997/98-1999/2000. Beldman et al. (2003) also analyze farm management adjustments.

the link between DRAM and the input-output model is described in chapter 5, Appendix G and Appendix H. In the analyses of the economic and environmental effects of MINAS and MAO, manure markets play a decisive role. In section 6.2 the theoretical background and a graphical example of manure demand and supply is presented to further explain how market prices of animal manure are formed in DRAM. Section 6.3 describes the scenarios that are analyzed with DRAM. Section 6.4 contains a discussion of the results of the scenarios. In section 6.5 the results of the sensitivity analyses are presented. This chapter ends with discussion and conclusions.

6.2 Theoretical background

DRAM is based on the neoclassical economic theory of behavior of economic agents. Crucial assumptions are that producers maximize profit and that markets are perfectly competitive. Based on this neoclassical framework of profit maximization, dual price relationships e.g. between nutrients and animal manure demand and supply, can be derived from setting up the primal Lagrange function and applying Kuhn-Tucker conditions (Hazell and Norton, 1986; Howitt, 2002).

In DRAM the nutrients (nitrogen (N) and phosphorous (P)) requirement, either from animal manure or mineral fertilizer per crop per hectare, is fixed (see restriction A.5 in Appendix A). The shadow demand price of nutrients (π^{5}_{ifr}, see restrictions A.5 in Appendix A and B.4 in Appendix B) equals the exogenous price of nutrients from mineral fertilizer if mineral fertilizer is used. The shadow price is below the price of nutrients from mineral fertilizer when animal manure only is used and when nutrient application does not exceed the minimum requirement. Hence, the shadow demand price of nutrients is only partly endogenous and related to the application of nutrients from animal manure. Assuming a fixed amount of nutrients from animal manure per crop and assuming that nutrients requirements are not exceeded, a downward and linear shadow demand curve of nutrients from animal manure, can be derived from the equilibrium conditions provided by restrictions B.2a, B.2c and B.2d in Appendix B. Due to the assumption of a fixed amount of nutrients from animal manure per crop, the increase of the land allocated to crops, linearly increases demand of nutrients from animal manure. The increase of the land allocated to the crops also increases marginal costs per unit. This in turn will decrease the demand price of animal manure until marginal costs and marginal revenue per unit are in equilibrium again.

Manure is a by-product of livestock activities. The producer price of animal manure (or marginal production cost) can be derived from the equilibrium conditions given by restrictions B.2a and B.2b in Appendix B. This means that the producer price of manure should be smaller than or equal to the marginal production costs minus revenues of final outputs and intra-sectorally produced inputs (other than manure) from livestock activities. Assuming a constant manure excretion per head, the marginal costs of animal manure, derived from the marginal costs function of livestock activities, can be expressed as a linear function of manure production level.

Figure 6.1 is a graphical representation of a regional manure market in DRAM for a specific type of animal manure. The derived marginal costs of animal manure supply is indicated by the upward line MC in figure 6.1. The downward line MR indicates animal manure demand. Profit-maximizing application of this specific type of animal manure is indicated by the intersection between the lines MR and MC. The market price of animal manure equals π^4_{ar} and the profit-maximizing demand equals Q_{ar}.[25]

[25] Note that manure prices in the Netherlands in the base are negative (chapter 4). Figure 6.1 shows positive manure prices to simplify the graphical model. The reasoning behind the figure is the same for negative and positive manure prices.

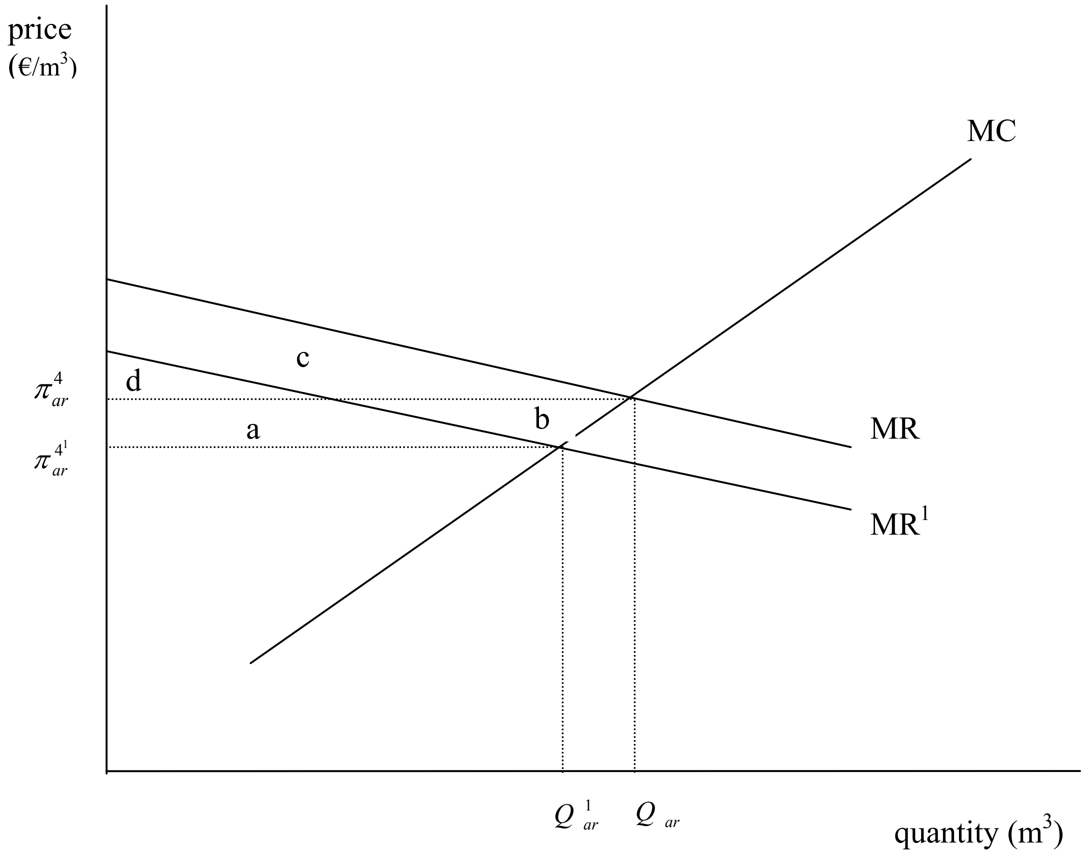

Figure 6.1 Example of a manure market

We will now assume that manure policies are tightened and manure application restrictions in the model become binding. In this case manure demand decreases from MR to MR^1. Along the line MC, the application of animal manure decreases to Q^1_{ar} and the price of animal manure decrease to $\pi^{4^1}_{ar}$. The policy change results in a profit change for the agricultural sector as a whole as indicated by area -(b+c). This loss represents changes in producers' surplus -(a+b) of animal manure production activities (e.g. fattening pigs activities, etc.) due to a loss of net production value measured as the area above the line MC and under the price line $\pi^{4^1}_{ar}$ minus the area above the line MC and under the price line π^4_{ar}. The change in the producer surplus of users of animal manure (e.g. consumption potatoes) is indicated by the area a-c. This is measured as the area above the price line $\pi^{4^1}_{ar}$ and under the line MR^1 minus the area above the price line π^4_{ar} and under the line MR.

6.3 Scenarios

MINAS threshold levels and levies on nutrients surpluses above threshold levels until 2004 are presented in Appendix 6.1. Under MAO the maximum application of nitrogen from animal manure in 2004 equals 250 kg N per hectare for grassland and 170 kg N per hectare for arable land including fodder maize. Excretion of nitrogen per animal under MAO equals 85% of nitrogen in manure under MINAS. The base scenario is a simulation of Dutch agriculture in 1996. The remaining scenarios are the following:

- S1: MINAS 2004 threshold levels and corresponding levies and MAO are assumed to be introduced in the base, with exogenous variables at base period (1996) levels. To bridge the long period between manure policies in 1996 and 2004, the following farm management adjustments are taken into account:
  - 12% increase in milk production per dairy cow activity;
  - 5%, 20% and 40% decrease in minimum workable nitrogen (N) input per hectare grassland for dairy cow activities with low nitrogen input per hectare grassland (LMLN, MMLN, HMLN), medium nitrogen input per hectare grassland (LMMN, MMMN, HMMN) and high nitrogen input per hectare grassland (LMHN, MMHN, HMHN) respectively. This recognizes the fact that more adjustments can be expected for grassland activities with relatively high nitrogen (N) input levels;
  - 25% increase in workability of nitrogen in animal manure applied to grassland and fodder maize and linked to dairy cows activities;
  - 25% decrease in manure production in the field by grazing dairy cows;
  - 15% increase in grassland production per hectare grassland;
  - All other exogenous variables remain unchanged.
- S2: idem S1 and
  - Nutrients excretion per type of animal equal to 2003 standards given by van Staalduinen et al. (2002) and van Staalduinen et al. (2003).[26] Nutrients excretion of beef cattle and fattening calves is assumed constant;

[26] From the early nineties, nitrogen (N) and phosphorus (P) excretion of sows and fattening pigs on the one hand and laying hens on the other, have decreased by -5 to -10% and -15 to -30% respectively (Statistics Netherlands, different years).

  - 250% increase in the export of manure from laying hens and meat poultry (van Staalduinen et al. 2002; van Staalduinen et al., 2003). Moreover, all the manure from meat calves is processed so that nutrients leave the agricultural sector;
  - all other exogenous variables remain unchanged.
- S3: idem S2 and an increase in manure acceptation by arable farmers to 170 kg N per hectare. All other exogenous variables remain unchanged.

Note that we analyze the economic and environmental effects accompanied by different assumptions, including manure policy standards from 1996 and MINAS nutrient threshold levels from 2004, plus corresponding levies and MAO manure utilization standards.

6.4 Results

Agricultural production

Results with respect to the number of animals and the allocation of land to crops in the base and illustrated by different scenarios are presented in table 6.1. Under S1, fewer dairy cows are needed to produce the milk quota due to an (partly exogenous) increase in milk production per dairy cow. The decrease in the number of dairy cows will ease the pressure on manure markets and this limits the effect of MINAS 2004 and MAO on the numbers of animals in other livestock industries. Nevertheless, under S1 the number of beef cattle decreases by 38%, while the number of pigs decreases by 12%. Under S2 and S3, the effects on pigs and poultry production in the Netherlands are rather limited. Under S3, the number of beef cattle decreases by 26% while the effect on the number of pigs is limited to -5%.

Table 6.1 Percentage change in livestock numbers and land use under different scenarios (base in 1000 animals or 1000 hectares)

	Base	S1	S2	S3
Cows	1653	-10	-10	-10
Beef cattle[1]	449	-38	-34	-26
Meat calves	620	-5	3	3
Sows	1268	-4	-2	-1
Pigs	6965	-12	-8	-5
Poultry	90,104	-8	-5	-4
Grassland	1030	-3	-4	-6
Fodder maize	221	-2	-2	-4
Cereals	199	11	14	19
Other crops	448	4	5	8

1. In livestock units.

Table 6.1 also shows the effects for crop activities. Under S1, the area of grassland and fodder maize decreases by 3% and 2% respectively. This is the net result of two effects that work in opposite directions. On the one hand the area of grassland and fodder maize decreases due to a reduction in the number of dairy cows and beef cattle and a related fall in demand. Moreover, the yield per hectare of grassland increases as well. On the other hand there is an increase in demand for grassland due to a switch to extensive production methods in dairy farming.

Under S1, the area for cereals and other crops increases by 11% and 4% respectively. These percentages increase to 19% and 8% respectively when arable activities accept more animal manure under scenario S3. The growth in the group of other crops under S1 to S3 are largely crops with relatively low profits per hectare e.g. legumes, fodder crops and non-food production.

Regional effects and technological shift in milk production

The regional effects on agricultural production can differ greatly from the national average. In scenario S1, the decrease in the number of dairy cows ranges from about 2% in the Northern peat region to 33% in the Southern clay region. Under scenario S2 and S3 the same kind of differences are found although here they are less pronounced. Regional effects for the number of beef cattle can differ too. Under S1, the number of beef cattle decreases by 55% in the Southern sand region, while in the Northern sand region and the Northern and Western peat regions the decrease in the number of beef cattle is limited to 20%. The regional differences in the effects on the intensive livestock industry are less pronounced. For example, the decrease in the number of pigs ranges from 14% in the Southern sand region to 10% in the Northern clay region. Under S1, the effect on the area of grassland ranges from –17% in the Southern sand region to +9% in the Northern clay region. The effect on hectares of fodder maize ranges from +7% in the Eastern sand region to –20% in the Northern and Southern clay regions. S1 also shows a decrease in area of cereals in the Northern clay region (4%), while the area of cereals increases by more than 80% in the Eastern sand region and 65% in the Southern sand region.

With MINAS and MAO and exogenous management adjustments taken into account, the optimal technology in dairy farming moves into the direction of extensive production methods. Table 6.2 shows that the scenarios favour the re-allocation of milk production in the Netherlands from more intensive type of dairy cow activities to relative extensive type of dairy cow activities. Differences in the share of extensive type of dairy cow activities in total regional milk production, also explains the effects of the scenarios on regional milk production (table 6.3). Table 6.3 shows that milk production increases in the peat regions, but decreases in the sand and in the remaining regions. A technical explanation is that the farm management adjustments will increase the shadow price of milk quota. As milk quota becomes more expensive, extensive production systems and regions with a relative large share of extensive production methods in regional milk production are now more competitive because of the relative low variable costs per kilogram milk.

Table 6.2 Percentage change in milk production per type of dairy cow under different scenarios (base in 1000 tonnes)

	Base	S1	S2	S3
Milk production				
(kg per dairy cow)				
LOW	5,024	4.1	4.9	5.1
MEDIUM	4,619	-1.2	-1.7	-1.9
HIGH	1,807	-8.3	-9.1	-9.4
Total	11,451	0.0	0.0	0.0
Nitrogen from mineral fertilizer				
(kg N per hectare grassland)				
LOW	2,759	11.8	12.1	11.6
MEDIUM	4,821	-4.1	-4.4	-4.3
HIGH	3,871	-3.2	-3.1	-2.8
Total	11,451	0.0	0.0	0.0

Milk production (kg per dairy cow): LOW <6500; 6500 < MEDIUM < 7500; HIGH > 7500;
Nitrogen from mineral fertilizer (kg N per hectare grassland): LOW < 250; 250 < MEDIUM < 350; HIGH > 350

Table 6.3 Percentage change in regional milk supply under different scenarios (base in 1000 tonnes)

	Base	S1	S2	S3
Sand[1]	4,429	-3.6	-4.3	-4.8
Peat[2]	3,189	8.8	9.0	9.4
Remaining regions[3]	3,832	-3.2	-2.5	-2.3
Total	11,451	0.0	0.0	0.0

1.Eastern sand region, Southern sand region, Central sand region; 2.Northern peat region, Western peat region; 3.Northern clay region, Northern sand region, Central clay region, Southern clay region, River area, Loess area, Peat colonies, Rest of Northern Holland, Rest of Southern Holland.

Profit

Table 6.4 and table 6.5 show the effects on profits in a number of selected industries and the economy as a whole. Here profit is defined as revenues minus variable costs. Table 6.4 shows an increase under S1 in profits from dairy farming and arable farming, including vegetables in the open and flower bulbs, of about 5.0%. The first is explained by the farm management adjustments defined under S1. The latter is the net result of (1) lower prices for especially vegetables in the open and flower bulbs due to a small increase in supply, (2) the increased production of cereals and other arable crops in particular and (3) higher profits from manure acceptation (see section 6.2 and Appendix B). Under S1, the effect on profits is especially large for pig and poultry farming, -13.6% and –11.5% respectively. This is explained by the increased costs of manure removal from farms. In absolute values the average national producer price of pig manure increases from € 6 per m^3 in the base to about € 14 per m^3 under S1.[27] In absolute values the average national producer price of manure from laying hens and meat poultry increases from € 8 per m^3 in the base to € 24 per m^3 under S1 and from € 2 per m^3 in the base to € 25 per m^3 under S1 respectively. Under S1 a big decrease in the number of beef cattle is expected and profit in the beef cattle industry decreases by about 17% compared to the base. The effect on profits at the beef cattle industry level is slowed down by lower marginal costs per head, due to (among other things) cheaper prices of grass. The average national price of grass decreases by 17% under S1.

Table 6.4 Percentage change in profit for primary agricultural industries under different scenarios (base values in million €)

	Base	S1	S2	S3
Dairy farming	2,116	4.9	6.1	6.3
Beef cattle	148	-17.0	-22.6	-23.6
Meat calves	71	-5.5	-2.2	-2.3
Pig farming	740	-13.6	-8.1	-5.7
Poultry farming	231	-11.5	-5.2	-4.2
Arable farming, incl. vegetables in the open and flower bulbs	1,417	4.9	3.0	2.8
Other agriculture	3,190	0.1	0.1	0.1
Total agriculture	7,913	0.2	0.9	1.1

Under S2 and S3, profits in the livestock industry improve compared to S1, except in the beef cattle industry.[28] The increase in profits in pig and poultry farming under S3

[27] Here, the producer price of manure is a positive number representing the amount that the producer needs to pay to the user of animal manure.

[28] Note that profits in arable farming also decrease under S2 and S3 compared to S1. This is due to lower profits from manure acceptation. Also note that profits under S3 decrease compared to S2. This is explained by the negative effect of S3 on profits from remaining grassland and fodder maize activities. To calculate the profits at industry level, profits from remaining grassland and fodder maize activities are partly accounted to the arable industry, vegetables in the open and flower bulb industry.

compared to S1, is explained by lower manure prices due to a lower figure for manure excretion per animal in these industries, increased exports of manure from poultry, increased processing of manure from meat calves and the increased acceptation of animal manure in the arable industry. In absolute values the average national price of pig manure decreases from about € 14 per m^3 under S1 to about € 10 per m^3 under S3. In absolute values the average national price of manure from laying hens decreases from about €24 per m^3 under S1 to € 13 per m^3 under S3.

Table 1 in appendix 6.2 shows the percentage change in total profits per activity group and region under different scenarios. Under S1, the change in total profits from dairy cow activities ranges from -4% in the sand regions to +19% in the peat regions. These effects are the result of the policy change in combination with farm management adjustments and the resulting changes in regional allocation of milk production. More detailed results (not presented here) show that changes in profits range from −11% for dairy cow activities with high nitrogen from mineral fertilizer per hectare of grassland (intensive production methods) in the sand regions, to +24% for dairy cow activities with low nitrogen from mineral fertilizer per hectare of grassland (extensive production method) in the peat regions. Table 1 in appendix 6.2 shows that under S1 the effect on total profits from arable activities, vegetables in the open and flower bulbs ranges from +6% in the sand regions to +3% in the remaining regions. Under S1, total profits from remaining agricultural activities included in DRAM (e.g. beef cattle, fattening pigs, sows, remaining grassland, remaining fodder maize, etc.) decrease by 14% in the sand regions and 6% in the remaining regions. The effects of the scenarios per region depend on the effects per activity group and the share of the activity groups in the total agricultural production per region. Under S1 total profits from agriculture, as described in DRAM[29], decrease by 7% in the sand regions but increase by 14% in the peat regions.

Table 2 in appendix 6.2 shows the effects on profits per hectare per activity group per region. Under S1, the profits per hectare for dairy cow activities in the peat and sand regions increases by +22% and +9% respectively. This positive effect on profits per

[29] The category 'other agriculture' as included in table 6.3 is not included in DRAM, but the effect presented in table 6.3 comes from the IO model linked to DRAM.

hectare for dairy cow activities is explained by the increase in milk production per dairy cow under S1. Table 2 in appendix 6.2 shows that under S1 the profits per hectare from arable farming, vegetables in the open and flower bulb activities decrease, particularly in the sand regions (18%). This can be entirely explained by the increased share of arable activities with low profits per hectare in total regional cropping plan of arable, vegetables in the open and flower bulb activities as compared to the base.

By calculating the profit per kilogram of milk per dairy cow activity per region and by applying assumptions concerning the milk production per farm under different scenarios, DRAM also allows for a calculation of the changes in the profits per farm. Under S1, the effect on farm profits for the average dairy farm with a production of 350.000 kg milk in the base both before and after the policy switch, ranges from about € -334 per dairy farm in the sand region to about € 6,300 per dairy farm in the peat region. The differences in the sand regions in particular are relatively large, ranging from about € –1,500 per farm with intensive production methods to € 2,300 per farm with extensive production methods.

Table 6.5 Differences in profits from agriculture, agricultural processing and input delivering industries under different scenarios (in million €)

	S1	S2	S3
Total agriculture	19	68	87
Dairy product manufacturing	0	0	0
Meat industry	-127	-83	-62
Other output processing industries	5	8	10
Agricultural input delivering[1]	-306	-196	-147
Other industries	-20	-13	-11
Total Netherlands	-429	-216	-122

1. Includes the transport of young animals and manure.

Table 6.5 shows the effect on profits in a number of selected industries and the economy as a whole. Due to the decrease in the intensive livestock industry under S1, profits in the meat industry decrease by €127 million or 12% compared to the base. Profits in other output processing industries increase due to an increased supply from arable farming, vegetables in the open and flower bulb farming. In absolute figures the profits in the input delivering industries decrease the most, that is € 306 million under S1 compared to the base. The total effect of S1 on the Dutch economy is a decrease in profits of € 429 million. Further adjustments included in scenarios S2 and S3 reduce this effect on the economy as a whole to € 216 million and € 122 million respectively. In general, table 6.5 shows that in absolute terms, the economic effects for the rest of the economy by far exceed the economic effects for agriculture.

Nitrogen balance

Table 6.6 shows the effects on the nitrogen (N) balance as calculated by the surface balance method (see chapter 4). Under S1 the total application of nitrogen (N) from animal manure to the soil decreases by 12%. The input from mineral fertilizer decreases as well (21%). On the output side, the uptake of nitrogen (N) by crops increases. This is partly explained by the increased production per hectare of grassland. Manure export and processing increase by about 212% compared to the base. This is explained by the increased processing of poultry manure to about 1.1 million m^3 under S1. Due to the decrease in manure production the emission of nitrogen (N) as ammonia also decreases (13%). The changes in input and output components of the nitrogen (N) surface balance result in a decrease of the net nitrogen

(N) surplus of 46%. Further adjustment of management practices in livestock industries under S2 and S3 hardly affect the net nitrogen (N) surplus at the surface balance. Under S2 and S3 the net nitrogen (N) surplus as compared to the base, decreases by 50% and 51% respectively. The emission of nitrogen (N) as ammonia under S3 increases to the observed level in the base.[30]

Table 6.6 Percentage change of elements of the nitrogen (N) balance (excluding deposition and rest component). Base values in kg N per hectare.

	Base	S1	S2	S3
Input				
Animal manure	318	-12	-18	-17
Mineral fertilizer	203	-21	-16	-19
Output				
Uptake by crops	215	7	6	6
Manure export and processing	8	212	91	78
Emission of nitrogen as ammonia	80	-13	-3	0
Net surplus surface balance	219	-46	-50	-51

Regional effects on the net nitrogen (N) surplus at the surface balance can be quite different from the average national effect. Under S1 differences with the base range from about –80% in the Southern sand region to –26% in the Central clay region.

Tables 3 and 4 in appendix 6.2 show the gross nitrogen (N) balance per activity group in the base and under scenario S2 respectively. Land allocated to dairy cow activities decreases from about 1 million hectare in the base to 0.93 million hectares under S2. This is explained by the decrease in the number of dairy cows and the increased grassland production per hectare of grassland. Therefore, less grassland is needed to feed the dairy cows. At the same time the area allocated to the group of arable activities, vegetables in the open and flower bulbs and to the group of remaining grassland and fodder maize activities increases from about 647 thousand hectare in the base to 697 thousand hectare under S2. Table 4 compared to table 3 in Appendix 6.2 show an increase in the application of manure from dairy cow activities to arable crops and remaining grassland and fodder maize activities. The average gross nitrogen

[30] This is explained by differences in nutrients in manure and nutrients in total in manure under S2 and S3 as compared to the base. As a result the emission of nitrogen (N) as ammonia in animal housing increases sharply.

(N) surplus per hectare for the group of dairy cow activities decreases from 361 kg N per hectare in the base to about 161 kg N per hectare under S3. This is equal to a change of –55%. At the same time the average gross nitrogen (N) surplus for the group of arable activities and remaining grassland and fodder maize activities decreases by 15% and 18% respectively.

Table 6.7 Sensitivity analysis, percentage change in some selected variables under S2 and S2 with limited farm management adjustments in dairy farming.

	Base	S2	S2 with limited farm management adjustments in dairy farming
			%
Dairy cows (1000 head)	1,653	-10	-5
Beef cattle (1000 head)	450	-34	-43
Fattening pigs (1000 head)	6,965	-8	-10
Poultry (1000 head)	90,104	-5	-6
Grassland (1000 ha)	1,030	-4	-2
Fodder maize (1000 ha)	221	-2	-4
Cereals (1000 ha)	199	14	6
Profits dairy farming industry (million €)	2,116	6.1	-4
Profits pig industry (million €)	740	-8.1	-10.4
Profits arable farming, vegetables in the open and flower bulbs (million €)	1,417	3	5.2
			Million €
Profits total agriculture (million €)	7,916	68	-134
Profits total economy (million €)	226,025	-216	-472
			%
Emission of ammonia (kg N per ha)	80	-3	-12
Net nitrogen surplus (kg N per ha)	219	-50	-40

6.5 Sensitivity analysis

As was noted in the introduction to this chapter it is difficult to distinguish between autonomous developments and policy-induced effects. Therefore, in this section we research the effects of scenario S2 including farm management adjustments at dairy farms that are only half of the original S2 percentage changes. For example, in

relation to the policy change we can assume an increase in milk production per dairy cow of 6% instead of 12%. The results are presented in table 6.7.
Under scenario S2 with limited farm management adjustments the number of dairy cows decreases by 5%. This is a change of –10% compared with the original S2 scenario. Under S2 with limited farm management adjustments the number of beef cattle decreases by 43%, a change of –34%. The number of fattening pigs decreases by 10%, a change of -8% compared with the original S2 scenario. These differences are explained by higher manure prices under the new S2 scenario compared to the original, as a result of higher nutrients and manure production from dairy cows. Land allocated to grassland decreases with 2%, this was 4%. This effect is due to the higher number of dairy cows and the lower grassland production under the new S2 scenario. Under the new S2 scenario profits in the dairy farming industry decrease by 4% compared to the base. Detailed results show that under the new S2 scenario, total profits from dairy cow activities decrease by 13% and 3% in the sand and remaining regions respectively. Profits from dairy cow activities increase by 7% in the peat regions. Due to higher manure prices profits in the pig industry decrease by 10.4% under the new S2 scenario. Due to higher profits from manure acceptation, profits in arable farming increase by +5.2% compared to the base. Table 6.7 shows that the total profit in agriculture under the new S2 scenario decreases by €134 million. Under the original S2 scenario this increase was € 68 million. Total profits in the rest of the economy decrease by € 472 million. Under the new S2 scenario, net nitrogen (N) surplus and emission of nitrogen (N) as ammonia decrease by 40% and 12% respectively compared to the base.

6.6 Discussion and conclusion

In this section we start with a comparison with other studies. We then summarize the results of this chapter and we finish this section with a number of conclusions concerning the method and the results presented in this chapter.

Recent farm-level studies provide an insight into the effects of MINAS and MAO at the farm level (de Hoop ed., 2002; Van der Kamp ed., 2002). Results from van der Kamp ed. (2002) show that in the clay and peat regions the loss of profits is approximately € 700 per dairy farm, including MINAS 2002 and 2003 standards. In areas characterized as dry sand/loess areas, the loss of profits is estimated to be about € 1,000 per dairy farm. This is explained by the fact that nitrogen threshold levels are 40 kg per ha lower in these areas. Our study indicates that the accumulated economic effects based on manure standards in the base period (1996) and MINAS standards (2004) for the dairy industry as a whole will be very limited or even positive if all the possible farm management measures are taken into account. However, there are big differences between regions and dairy cow activities. Moreover, the economic effects are highly sensitive to the farm management adjustments that were taken into account.

Intensive livestock farms in the Netherlands are characterized by the fact that most farms have no or very little land. Hence, the economic effects of MINAS for intensive livestock farms are mainly determined by changes in manure prices. Van der Kamp ed. (2002) assumes that manure prices increase from € 6.80 in 1998 to € 11.34 in 2002 and 2003. In our study the prices of manure from fattening pigs increases from € 5.90 in the base to € 9.70 under scenario S3. With respect to arable farms, Van der Kamp ed. (2002) expects a positive effect on profits from MINAS and MAO including policy standards from 1998 to 2003/2003. This is explained by higher prices of animal manure. The positive profits effect for arable farmers is confirmed by this study.

There are also studies that take into account the effect of manure and nutrients policies on the rest of the Dutch economy (De Hoop and Stolwijk eds. 1999; Komen and Peerlings, 1998). De Hoop and Stolwijk use an input-output model. Results are driven by changes in the final demand of livestock based on expert opinions[31]. De Hoop and Stolwijk (1999) estimate the profit effect for the economy as a whole to be € - 492 million (1998 prices). Komen and Peerlings (1998) use an Applied General Equilibrium (AGE) model. The national manure surplus resulting from different permitted standards for phosphate loss are translated into a reduction of livestock numbers. Nitrogen loss standards are not taken into account. The effects of a reduction in the numbers of pigs and poultry are compared with a reduction in the number of pigs only. A reduction in beef cattle is not considered. Effects on national profits of a permitted phosphate loss standard of 30 kg per ha, ranges from € - 211 million (1990 prices) as a result of a reduction in the number of pigs and poultry, to € - 328 million (1990 prices) as a result of a reduction in the number of pigs only. Komen and Peerlings (1998) take into account possible changes in output prices of pigs and poultry production due to a decrease in supply in the Netherlands. Results from both studies on economy wide effects exclude the higher transportation costs of animal manure and the increased profits in arable farming. Moreover, manure markets are not explicitly taken into account.

This chapter aims to analyze the environmental and economic effects of MINAS 2004 threshold levels for nutrient losses and related nutrients levies combined with manure application standards from MAO. The policy changes are simulated as if they were introduced in the base. The fairly detailed description of agricultural production enables us to take into account farm management adjustments from farm level studies in order to bridge the long period between manure policies in the 1996 base and those in 2004. A sensitivity analysis shows the effect of different levels of farm management adjustments so as to counteract policy and market changes.

Results show that MINAS 2004 and MAO mainly affect production in the beef cattle and intensive livestock industries, including intensive dairy farming. The results also show that farm management measures induced by policy change reduce the net nitrogen (N) surplus in the soil balance by more than 50%, while profits in agriculture as a whole increase by about 1.1% or € 91 million. However, the effects on agricultural profits are differ greatly per industry and region. MINAS 2004 in combination with MAO reduce profits in the dairy farming industry in the sand region with 4%. At national level profits in beef cattle and pig industries decrease by 23.6% and 5.7% respectively. For the Dutch economy as a whole, the effect on profits is limited to € -122 million. However, due to the uncertainties particularly concerning farm management adjustments induced by the policy change it is concluded that the economic effects for the economy as a whole range between € -122 million and € -472 million. In general, the scenarios presented in this paper show that in absolute terms

[31] According to experts' opinions the number of beef cattle, meat calves, pigs and poultry decreases by –30 %, -10 %, -15 % and –20 % respectively due to the tightening of manure and nutrients policies. These are short to medium term effects as the assumed adjustment period is from 1998 to 2002 (de Hoop and Stolwijk, 1999).

the effect on profits in the rest of the economy by far exceeds the effect on profits in agriculture.

DRAM can be characterized as a short to medium term model since technology is fixed in agriculture. In the longer term alternative technologies may become available. Investment costs connected to exogenous farm management adjustments are not taken into account in this study. Furthermore, some farmers will not have the capacity (nor the wish) to adopt the required measures and so achieve the assumed management levels in relation to milk production per dairy cow, manure handling and grassland management. Increased investments costs and a lack of management capacity to cope with manure and nutrients policies after 1996, have probably accelerated the decrease in the number of farms and the increase in farm size.

Uncertainties that can be identified are nutrients production, the uptake of nutrients by crops, acceptation of different types of animal manure, manure export to other countries, the costs of mineral fertilizer application, spatial distribution of an environmental impact[32], manure processing costs and changes in farm management. Moreover, the farm management adjustments that are taken into account are not differentiated per region or technology (type of dairy cow). With more information available, especially by close cooperation with regional experts and the application of DRAM in interdisciplinary research, this could be improved upon.

Notwithstanding the uncertainties, it is believed that the modeling system offers a flexible and consistent tool for policy analysis at the Dutch agricultural industry and economy levels.

[32] DRAM implicitly assumes that crop and livestock production and the related environmental effects are evenly distributed in a region.

Appendix 6.1 MINAS nutrients threshold levels and levies

Table 1 MINAS nutrients (nitrogen (N) and phosphorus (P)) threshold levels, in kg per ha per year

	1998-1999	2000	2001	2002	2003	2004
Phosphorus loss standard						
- arable land	17.47	15.28	15.28	13.10	10.92	10.92
- grassland	17.47	15.28	15.28	10.92	8.73	8.73
Nitrogen loss standard						
- arable land clay/peat regions	175	150	150	150	100	100
- arable land dry sand/loess	175	150	125	100	80	60
- grassland	300	275	250	220	180	180
- grassland dry sand/loess	300	275	250	190	160	140

Source: Ministry of Agriculture, Nature Management and Fisheries (2002a; 2002b).

Table 2 Levies on nutrients surplus above threshold level, in € per kg.

	1998-1999	2000	2001	2002	2003>
Phosphorus (P)					
0 - 4.37 kg /ha	2.60	5.20	5.20	20.78	20.78
> 4.37 kg/ha	10.39	20.78	20.78	20.78	20.78
Nitrogen (N)					
0-40 kg/ha	0.68	0.68	0.68	1.13	2.27
> 40 kg/ha	0.68	0.68	0.68	2.27	2.27

Source: Ministry of Agriculture, Nature Management and Fisheries (2002a).

Appendix 6.2 Selected results for activity groups and regions

Table 1 Percentage change in profits per activity group and region under different scenarios (base values in million €)

Activity groups and regions	Base	S1	S2	S3
Dairy cows				
Sand[1]	829	-4	-4	-4
Peat[2]	590	19	21	21
Remaining regions[3]	697	3	5	6
Netherlands	2,116	5	6	6
Arable crops, vegetables in the open and flower bulbs				
Sand	254	6	4	6
Peat	91	3	2	3
Remaining regions	1,034	4	3	3
Netherlands	1,379	4	3	3
Remaining activities				
Sand	881	-14	-9	-7
Peat	87	-8	-10	-9
Remaining regions	261	-6	-8	-9
Total	1,228	-12	-9	-8
All activities				
Sand	1,964	-7	-5	-4
Peat	767	14	15	16
Remaining regions	1,993	3	2	2
Netherlands	4,724	0	1	2

1. Eastern sand region, Southern sand region, Central sand region; 2. Northern peat region, Western peat region; 3. Northern clay region, Northern sand region, Central clay region, Southern clay region, River area, Loess area, Peat colonies, Rest of Northern Holland, Rest of Southern Holland.

Table 2 Percentage change in profits per hectare per activity group and region under different scenarios (base values in €)

Activity groups and regions	Base	S1	S2	S3
Dairy cows				
Sand[1]	2,205	9	10	10
Peat[2]	1,899	22	23	23
Remaining regions[3]	2,111	18	19	20
Netherlands	2,081	15	16	17
Arable crops, vegetables in the open and flower bulbs				
Sand	2,455	-18	-21	-24
Peat	3,182	-1	-5	-10
Remaining regions	2,010	3	0	-2
Netherlands	2,133	-2	-4	-7
Remaining activities				
Sand	11,400	-28	-24	-16
Peat	2,963	-23	-18	-8
Remaining regions	2,030	-25	-22	-16
Total	5,222	-28	-22	-15
All activities				
Sand	3,527	-7	-5	-4
Peat	2,083	14	15	16
Remaining regions	2,047	3	2	2
Netherlands	2,488	0	1	2

1. Eastern sand region, Southern sand region, Central sand region; 2. Northern peat region, Western peat region; 3. Northern clay region, Northern sand region, Central clay region, Southern clay region, River area, Loess area, Peat colonies, Rest of Northern Holland, Rest of Southern Holland

Table 3 Use of nitrogen (N) from mineral fertilizer and animal manure per manure type, uptake of nitrogen by crops, total gross nitrogen (N) surplus and gross nitrogen (N) surplus per hectare per activity group in the base

		Dairy cows	Arable crops, including vegetables in the open and flower bulbs	Remaining grassland and fodder maize	Total
Available land	1000 ha	1,016	647	235	1,898
Mineral fertilizers	Million kg N	240	116	30	385
Total animal manure	Million kg N	370	67	74	510
- Dairy cows	Million kg N	317	2	1	319
- Beef cattle	Million kg N	13		27	39
- Pigs	Million kg N	38	39	33	109
- Poultry	Million kg N	3	26	14	43
Uptake by crops	Million kg N	242	112	54	408
Gross surplus	Million kg N	367	70	50	487
Gross surplus per ha	Kg N per ha	361	109	211	257

Table 4 Use of nitrogen (N) from mineral fertilizer and animal manure per manure type, uptake of nitrogen by crops, total gross nitrogen (N) surplus and gross nitrogen (N) surplus per hectare per activity group in scenario S2

		Dairy cows	Arable crops, including vegetables in the open and flower bulbs	Remaining grassland and fodder maize	Total
Available land	1000 ha	926	697	275	1899
Mineral fertilizers	Million kg N	156	122	45	323
Total animal manure	Million kg N	244	63	65	373
- Dairy cows	Million kg N	204	15	39	258
- Beef cattle	Million kg N	4	12	9	24
- Pigs	Million kg N	35	26	17	78
- Poultry	Million kg N	1	11	0	12
Uptake by crops	Million kg N	250	121	63	434
Gross surplus	Million kg N	149	65	48	262
Gross surplus per ha	Kg N per ha	161	93	173	138

7. Discussion and conclusion

7.1 Introduction

The purpose of this chapter is to assess if the research objectives with respect to model and data descriptions and the policy applications are met, and to discuss a number of strengths and flaws of DRAM.

7.2 Model description and data

DRAM is a mathematical programming model with a long history (Bakker, 1985; 1986). After introducing many adjustments and applications, the first research objective of this thesis was to describe the current state-of-the-art of DRAM. To this end a general description of DRAM was included in the first three chapters of this thesis. Moreover, detailed primal and dual mathematical descriptions of DRAM can be found in Appendix A and Appendix B respectively. The dual mathematical description of DRAM provides insight into the driving forces behind DRAM, as the FOCs for an optimal solution are included explicitly. An important scientific contribution is the modeling of manure demand and supply and manure prices in DRAM. In using the standard economic theory of profit maximization and perfect competition, it is demonstrated that the producer or supply price of animal manure is a function of the shadow price of nutrients in animal manure, the nutrient content of animal manure, the workability of nutrients in manure, the manure application costs, manure acceptation, transport costs of animal manure, export and import possibilities, costs of large scale manure processing, allocation of land over the crops and manure and nutrients policies. Animal manure is considered a by-product of livestock production. The producer price of manure should be lower than or equal to the marginal production costs minus the revenue of related final outputs and intra-sectorally produced inputs (other than manure) from livestock activities. Moreover, the upper limit of the producer price of animal manure is determined by the costs of large scale manure processing. The different variables that are included to describe manure markets allow for calculations of nutrient balances at soil level, including nutrients from animal manure and mineral fertilizers, the uptake of nutrients by crops, regional manure transport, manure export and processing, ammonia emission in animal sheds, pasturing and the application and nutrient surpluses as a resulting variable. In order to model manure acceptation and manure policies more realistically the mathematical programming approach allows us to include restrictions on groups of agricultural activities e.g. restrictions across all arable crops. Hence, nutrient balances can also be calculated over activity groups.

The detailed description of important agricultural markets is combined with the Positive Mathematical Programming (PMP) approach to calculate the parameters of activity-specific quadratic costs functions so that the observed activity levels are almost exactly reproduced (Howitt, 1995a). The PMP approach as applied in this thesis is described in detail in Appendix D. Contrary to the standard PMP approach (Howitt, 1995a), the parameters of the costs functions are derived from supply elasticities for both arable and livestock activities. The latter are checked against supply elasticities found in the literature.

The second research objective of this thesis was to give a detailed description of the database. DRAM needs detailed descriptions of profits in terms of prices and quantities of inputs and outputs at the activity level per region. Data are described in chapter 4 of this thesis and in Appendix C. The focus of Chapter 4 is on environmental data such as manure production, manure application and manure prices. A more general data description is provided in Appendix C. The most important data sources are the Dutch Farm Accountancy Data Network (FADN) and the Dutch Agricultural Census (CBS). Data from specialized farms included in the FADN are used to calculate prices and quantities of produced outputs and used inputs per activity. These data are linked to activity levels taken from the agricultural census in order to determine total regional agricultural input use and agricultural production. FADN is of limited use for our purposes. The first limitation is the farm level approach to bookkeeping and additional work will be necessary to distribute all variable costs over activity levels. Different methods can be used to filter out the relation between costs per activity and costs at farm level (Léon, et al., 1999). Another limitation is the occasionally limited number of farms at the regional level. It is therefore not always possible to use FADN data at the regional level particularly with respect to intensive livestock activities. Because of the farm level approach in FADN, data on the use and produce of intra-sectorally produced inputs at the activity level such as grass and fodder maize, are also not available. However, FADN is a rich database for econometric estimation of input/output relationships. In this thesis results from Dijk, et al. (1995) are used to determine grass production and consumption per dairy cow activity.

A validation of DRAM against observed national use of nitrogen (N) and phosphorous (P) from mineral fertilizers, regional manure transport, manure prices and manure surplus can also be found in chapter 4. The validation of DRAM shows that calculated values of the above-mentioned variables are comparable with observed data. As the validation is still rather limited, a further test of the model's behavior outside the calibration period is desirable.

7.3 Simulation results and policy implications

This section summarizes the main results of the policy simulations and describes a number of policy implications.

CAP reform 2000/2008

Chapter 5 analyzes ceteris paribus the environmental and economic effects of what is called CAP Reform 2000/2008 in this thesis, in combination with partly or fully decoupled direct payments and milk quota abolition in Dutch agriculture. Moreover, a mixed input-output (IO) model is developed to extend the analysis to the Dutch economy as a whole. CAP Reform 2000/2008 includes the Agenda 2000 agreements of March 1999 and the further agreements to reform CAP of June 2003.

Results show that a complete introduction of CAP Reform 2000/2008 including partly or fully decoupled direct payments has a significant effect on production and profits in agriculture. Results vary per industry and region. The decoupling of direct payments has a negative effect on production in particularly the beef, meat calves and arable industries. Positive effects of decoupling on profitability in dairy farming and arable farming, including vegetables in the open and flower bulbs, are due to more production flexibility. However, the positive effects of decoupling are offset by lower intervention prices (for skimmed milk powder, butter, cereals, starch potatoes). Under CAP Reform 2000/2008 including fully decoupled direct payments, profits in dairy and arable farming, including vegetables in the open and flower bulbs, decrease by 5.2 % and 3.6 % respectively. Especially for dairy farming the effect of CAP Reform 2000/2008 is an important outcome in view of expected further pressures on profitability related to increased production costs because of tighter manure policies (chapter 6).

Changes in gross output in agriculture are introduced in a mixed IO model to calculate the economy wide effects of CAP Reform 2000/2008. It was found that economy wide effects of direct payment decoupling exceed the changes in primary agriculture.

An important policy implication is that under CAP Reform 2000/2008 the net nitrogen surplus and emission of nitrogen as ammonia will decrease when direct payments are fully decoupled from agricultural production, compared to the situation of coupled direct payments. This is the net result of a reduction in the number of beef cattle, the limited increase in the number of pigs and poultry and the decrease in manure export. However, due to changes in land use, manure export abroad and regional manure transport, the national and regional effects of CAP Reform 2000/2008 on environmental variables are very limited.

Milk quota abolition, when applied to the agricultural sector in the base situation, will increase milk production in the Netherlands by 27%. The increase in milk production is conditioned by Dutch manure policies. Due to the increase in manure and nutrients supplies as a result of the increased number of dairy cows, manure prices increase and production and profits in other livestock industries decrease. Environmental effects differ per region.

Abolition of the milk quota system will increase milk production in the Netherlands substantially in the short to medium term. However, profits in the dairy farming industry will decrease by 22%. This is among other things due to lower milk prices after the milk quota system in the EU is abolished and milk prices are determined by world market prices. A sensitivity analysis shows that profits decrease by 29% if higher prices of concentrates, due to increased demand, are also taken into account.

As a result of changes in the market price of some final outputs and intra-sectorally produced inputs, other agricultural industries are affected as well. Dairy manufacturing and agricultural input delivering industries benefit a lot from the economic gains of milk quota abolition. Abolition of the milk quota system will increase the intensity of dairy farming and this increases both the emission of nitrogen as ammonia and the net nitrogen surplus. Comparisons with other studies show that the increase in milk production after quota abolition is probably overestimated if future manure and nutrients policies are taken into account. The effects on profits and the environment show that abolition of the milk quota system can have very negative implications for the Dutch dairy farming industry as a whole. Of course, the economic effects can be different for individual farms.

Dutch manure policies

In chapter 6 DRAM is applied to analyze the environmental and economic effects of MINAS standards (2004) and MAO at the regional and industry levels. Results from farm level studies and other models are used to take into account exogenous technology switches and to bridge the long period between manure and nutrients policies in the 1996 base period and those in 2004.

Results show that MINAS 2004 standards combined with MAO reduces the net nitrogen (N) surplus by more than -50% compared to the base (1996), while profits in agriculture as a whole increase by about +1.1% or € 91 million, compared to the base. Effects on profits are very different per industry. On the one hand, profits in dairy farming and arable farming, including vegetables in the open and flower bulbs, increase by 6.1% and 3.0% respectively. Profits in the beef cattle and pig and poultry industries decrease by 22.6%, 8.1% and 5.2% respectively. For the Dutch economy as a whole, the effect is limited to a decrease of € 122 million.

To bridge the long period between 1996 and 2004, technology switches in dairy farming are partly exogenously added to the scenarios. It is assumed that all farmers are capable to adjust to higher management levels (new technologies) at zero investment costs. This largely explains the said positive effect on profits in dairy farming. It also partly explains the shift to extensive production methods. In reality it is likely that the required investments for management adjustments and improvements plus related costs will put profits in dairy farming under pressure. Moreover, farmers that are unable to adjust to the assumed management requirements will abandon dairy farming sooner or later. This will accelerate the decrease in the number of farms and the increase in farm size.

Additional analyses are carried out to obtain better insights into the sensitivity of the results with respect to exogenous variables, related in particular to management adjustments in dairy farming. When fewer farm management adjustments are included, total profits in dairy farming decrease by 4.0%. Regional effects on profits in dairy farming are especially large in the sand region (–13%). Economic effects on intensive livestock industries and the economy as a whole will increase as well. When the uncertainties as described above are taken into account it can be derived that the effect of MINAS 2004 standards combined with MAO on profits in the economy as a whole ranges between € -122 million and € -472 million as compared to the base (1996).

7.4 Strengths of DRAM

Standard economic theory

The driving forces behind DRAM are derived from standard economic theory. This improves the transparency of the model and the interpretation of the results. FOCs for an optimal solution that is derived from economic theory are also the basis of the calibration of DRAM. The application of the PMP approach enables the model to almost exactly reproduce observed activity levels in a base year. This has improved stakeholders' confidence. Moreover it has also improved the model's capability to realistically describe supply response to changes in exogenous variables. Communication of model results in general is relatively easy because DRAM is based on standard technical economic variables such as hectare per crop, number of animals and profits per activity.

Complete and consistent

Farm models concentrate on a subset of farms and the results are usually not representative for total land use, number of animals and connected agricultural production. Agricultural sector models like DRAM provide a complete, consistent and detailed description of regional agricultural production (multi-sector and multi-commodity) and include the modeling of joint resources. These are resources that are used by different production activities but whose availability is limited in the agricultural sector, especially land and manure application capacity. Manure application capacity is an important variable when analyzing manure and nutrients policies.

Another advantage of DRAM extended with a mixed input-output analysis is that backward and forward effects can be taken into account of changes in agricultural production on other industries, especially output processing, agricultural input delivering industries and the economy as a whole. Backward and forward economic effects are especially important because they might far exceed the effects for primary agriculture in terms of value. Whether this is the case or not depends on the policy scenarios at hand.

Agricultural sector models also offer the opportunity to analyze correlations between environmental themes, for example the link between manure production and related manure surpluses and use of pesticides. Chapter 6 shows that manure policies might decrease land allocated to roughage crops and increase land allocated to arable crops. Ceteris paribus, this leads to an increase in the total use of pesticides because their use per hectare in arable crop production exceeds the use of pesticides per hectare in roughage crop production (Helming, 1997 and 1998).

Markets

DRAM takes into account market price adjustments caused by changes in aggregated supply and demand of a number of agricultural outputs and intra-sectorally produced inputs (young animals, roughage and manure). This makes DRAM a rather unique tool for policy analysis in the Netherlands.[33] Mathematical programming models and econometric models of Dutch farms assume exogenous prices of inputs and outputs. As the effects of price changes on aggregate demand and supply are not available in these types of models, aggregation of results to regional or industry level will give biased results.

DRAM includes a limited number of markets for final agricultural outputs. This is because prices of agricultural products, particularly livestock products, are mainly determined at European market levels. DRAM does not contain the European dimension. One model which describes agricultural supply and demand at European market levels is the Common Agricultural Policy Regional Impact analysis (CAPRI) model developed at the University of Bonn with a consortium of other European universities and institutes (Heckelei and Britz, 1999 and 2000). CAPRI is an economic, mathematical programming model of European agriculture, describing agricultural production at NUTS II level.[34] CAPRI describes European agricultural markets in accordance with the Economic Accounts of Agriculture (EAA) (Eurostat, 2000). Production of agricultural outputs, including intra-sectorally produced inputs at the regional level, is iteratively linked to demand and prices at European market levels. This feature of consistency at European market levels is clearly an advantage of CAPRI compared to DRAM. Advantages of DRAM compared to CAPRI are the regional specification based on soil types and the focus on specialties of the Dutch agricultural sector with a more detailed description of dairy farming, regional manure markets and a further desaggregation of potato production into consumption potatoes, seed potatoes and starch potatoes.

Interdisciplinary approach

An important strength of DRAM is the interdisciplinary approach (Bakker, 1985 and 1986). This provides the opportunity to model in great detail the link between environment and economy and the correlations between different environmental themes. The following features of DRAM are important in this regard:

- ability to incorporate a wealth of physical detail (land availability and heterogeneity);
- behavioral response is strongly influenced by the physical structure;
- detailed description of regional agricultural production (multi-sector and multi-product approach)
- detailed modeling of nutrient production and use which is relevant for analysis of the manure policy;

[33] The uniqueness of DRAM also stems from the fact that the model has survived for many years and is still being used to analyze the effects of policy and technology changes at the agricultural sector level.
[34] In the Netherlands this is the level of provinces.

- regional desaggregation which is relevant because of differences in direct payments per region and structural and environmental differences;
- possibility to include constraints on groups of activities to mimic farm types instead of just single activities;
- use of economic, technological and environmental information.

The rather detailed description of agricultural production enables the model to analyze necessary technology changes in response to policy and market changes. An example of the effects of farm management adjustments is presented in Chapter 6. An interdisciplinary approach is needed to realistically determine technology changes at the regional and farm levels.

A more recent application of DRAM within an interdisciplinary research project was its contribution to the Green Piggery project.[35] For this project the technology set of DRAM was extended to organic pig activities. The PMP approach was used to calibrate organic pig production in DRAM to observed activity levels. In addition, results from consumer studies were used to model the substitution of organic pigs and conventional pigs from the demand side. In doing so a procedure was adopted applied by Lehtonen (2001) and derived from Dixit (1988) among others. Next, the model was used to analyze the share of organic pig production in the total pig production under different scenarios (Helming and Surry, 2004).

7.5 Points for improvement

Farm-specific policies

An increasing number of policies is directed at the individual farm level. Examples from the EU CAP are the fallow land requirement for farmers that grow more than 92 tonnes of cereals and the coupling of stocking densities with premium levels in animal production. Individual farms also differ with respect to the availability and quality of fixed inputs including quality aspects like soil types. There can also be considerable structural, technical and managerial differences. Policy analysis would require the

[35] The green piggery initiative was a collaborative project between the research organisations INRA (F) and Wageningen UR (NL) that aims to contribute to the developments in the pork sector (http://www.greenpiggery.org) .

modeling of individual farms plus farm aggregates. DRAM mimics farm behavior by disaggregating agriculture, specifying different technologies and imposing constraints on activities.

There are numerous examples of farm models that are used for policy analysis in the Netherlands. Most farm models currently in use are simulation models whereas calibrated profit maximizing mathematical programming models are not available at the farm level. Future research could focus more on these types of models. In doing so, calibration techniques based on PMP and as described in this thesis could also be applied at the farm level, see e.g. Paris and Arfini (1995) and Arfini, Donati and Paris (2003).

Complementary to farm models, aggregated modeling concepts are necessary to simultaneously model different markets and input allocation.[36] It is argued by Lankoski and Lehtonen (1998) that a sector model yields the first approximation of regional level impacts on production and environment, taking into account market behavior and changes in input allocation. However, the methodology to link the results from DRAM back to the farm level is as yet underdeveloped and therefore offers room for improvement.

Environmental variables

This study provides insights into the effects of policy changes on economic and environmental variables. Results with respect to environmental variables are presented at regional scale. Aggregated regional models implicitly assume that crop and livestock production and the related environmental effects are evenly distributed across the region. Depending on soil and climatic variability and differences at the farm level for example, the spatial distribution of an environmental impact may be quite heterogeneous and the real externalities might be over- or underestimated at aggregated levels. At spot level, complex biophysical models enable detailed descriptions of nutrient and chemicals flows in agriculture.

[36] For studies of agricultural economic problems in the Netherlands combining direct economic effect analysis at farm level combined with sector analysis at regional level using DRAM see Everdingen et al., 1999; de Bont et al., 2003a, de Bont et al., 2003b, de Bont et al., 2003c, de Bont et al., 2003d.

From the variability in soil and climatic characteristics at farm and regional levels it can be concluded that uniform regulations are less than optimal. Nevertheless policymakers have a strong preference for simple and uniform policy instruments in order to reduce administrative costs. There is therefore a great need for costs effectiveness analyses of different environmental policy schemes at the regional or national level, taking into account the variability of environmental characteristics in as much detail as possible (Schou et al., 2000). An example of a biophysical model with an economic objective function in the Netherlands is the so-called 'Waterwijs' system (van Walsum et al., 2002). The economic module in 'Waterwijs' is obtained by DRAM and linked with e.g. a model for regional hydrology, taking into account sub models for soil water, groundwater and surface water. This system enables optimization of agricultural production in one specific region in the Netherlands by allocating fixed inputs to many sub-regions along plus appropriate water management measures. The system takes into account stakeholders' preferences with respect to peak discharges, nutrient concentrations in groundwater and surface water, the biological value of nature areas and revenue from agriculture. The data requirement for these models is enormous, to describe for example soil characteristics and water flows in the sub-regions. A problem that needs to be solved before DRAM can be linked to biophysical models is that biophysical models are often calibrated at a lower level of aggregation. Howitt and Reynaud (2003) develop a disaggregation method that addresses the issue of scale differences between different models.

Data requirements

A policy model requires up to date information. DRAM's data requirements are met by the combined use of Agricultural Census, FADN and a wide range of other data. DRAM's extensive data requirements mean that updates are costly and requires broad expertise. Potential data problems especially occur in the category of environmental data, e.g. manure acceptation, manure transport, manure application costs, transport costs, workability of nutrients in manure, the amount of manure produced in the field and in animal sheds and manure prices. At LEI the so-called Manure and Ammonia Model (MAM) is used to model manure demand and regional manure transport (Groenewold et al., 2002). MAM offers a very detailed database with respect to manure types, housing systems and manure application techniques. Further

harmonization of variables in MAM and DRAM could improve the environmental data in DRAM.
Another data-specific problem in DRAM is that the link between the more aggregated variables (e.g. all beef cattle at regional level) used in DRAM and the corresponding original data (different types of beef cattle) should be maintained and guaranteed. To do this a so-called data model has proved very helpful and should be developed further (Koole, 2004).

Dynamics

Given the importance of sunk costs in agriculture and the fact that many policies have a long implementation period, a dynamic version of DRAM might be necessary if transition and development paths are of interest. Also, an important characteristic of agriculture is the relatively long time between the moment of decision-making and actual supply response.

A recently developed model of the Dutch agricultural sector that takes into account a ten year adjustment path or projection horizon is the Dutch AG-MEMOD[37] model (van Leeuwen and Tabeau, 2004). The Dutch AG-MEMOD model describes production and consumption of agricultural commodities in the Netherlands. A recursive dynamic approach is applied and results yield a ten-year time path for the effects of policy and market developments on national production and consumption. These effects can be compared to a base line scenario. AG-MEMOD is derived from economic theory and based on econometric estimates of relationships between prices and quantities at the national level. AG-MEMOD lacks the detail and interdisciplinary approach that are necessary to analyze the effects of most national agricultural and environmental policies. The regional dimension within countries is also lacking.

An econometric recursive dynamic model of the Dutch agricultural sector including models for capital investment and labor is the Wageningen Agricultural Sector (WAS) model (Oskam, 1986). The disadvantage of this model is the fairly high level of aggregation of the agricultural sector. Only a limited number of agricultural sectors is included and regional differentiation is not taken into account. Oskam (1986) also

[37] AG-MEMOD stands for Agricultural Modelling of the EU Member States.

mentions the difficulties in explaining and econometrically estimating agricultural market prices and investments at the macro level on the basis of annual data.

Lehtonen (2001) developed a dynamic agricultural sector model based on Recursive Programming (RP). This author applied a technology diffusion sub-model to make the process of technical change endogenous in the model. Investments and incremental improvement of existing technology are made dependent on prices, support, production quotas and other policy measures and regulations imposed on farmers. In the future technology diffusion might also be included in DRAM.

Processing of agricultural outputs

Agricultural products, particularly those from livestock industries, are processed into many products. To improve the modeling of agricultural prices it is preferable to further refine the modeling and to include supply and demand of processed agricultural products. In doing so, we could include processing costs and marketing margins at different levels of the supply chain. Insufficient data could be a problem. Because of the importance of dairy farming in the Netherlands and the asymmetric changes in intervention prices for skimmed milk powder and butter, priority should be given to milk processing activities which break down milk supplies into fat and protein component. Bouamra-Mechemache and Requillart (2000) present a short-term partial equilibrium model of milk supply, the processing stage and the demand for processed products. Another example is the model presented by Lehtonen (2001) which also includes some processing of milk products.

Appendix A Detailed mathematical presentation of DRAM, the primal NLP model

Introduction

The objective of this appendix is to give a full mathematical description of DRAM as a primal NLP model.

The objective function

Following standard economic assumptions on producer behavior and consumer behavior, DRAM assumes that farmers are maximizing profits and consumers are maximizing utility. In the objective function the sum of producers and consumers surplus is maximized, assuming that markets are perfectly competitive (Takayama and Judge, 1971). The objective function of DRAM is written as follows:

$$
\begin{aligned}
\max Z = & \overbrace{\sum_y \sum_r (\omega_{yr} - 0.5\varepsilon_{yr} Q_{yr}) Q_{yr}}^{1} - \overbrace{\sum_i \sum_r (kk_{ir} + \alpha_{ir} X_{ir} + 0.5\beta_{ir} X_{ir}^2)}^{2} \\
& - \overbrace{\sum_i \sum_f \sum_r p_{fr} F_{ifr}}^{3} + \overbrace{\sum_i \sum_r prem_{ir} X_{ir}}^{4} - \overbrace{\sum_i \sum_a \sum_r c_{iar} A_{iar}}^{5} \\
& + \overbrace{\sum_z \sum_r p_{zr}^e E_{zr}}^{6} - \overbrace{\sum_z \sum_r p_{zr}^i M_{zr}}^{7} - \overbrace{\sum_a \sum_r p_a^g G_{ar}}^{8} \\
& - \overbrace{\sum_z \sum_r \sum_{r'} (d_{rr'} vc_z + fc_z) T_{zrr'}}^{9}
\end{aligned}
$$

Manure policy after 1998 (MINAS and MAO)

$$
- \overbrace{\sum_f \sum_d \sum_r p_f^p P_{dfr}^d}^{10} - \overbrace{\sum_f \sum_r p_f^p P_{fr}^h}^{11} \qquad \text{A.0}
$$

$$
Q_{yr}, X_{ir}, F_{ifr}, A_{iar}, E_{zr}, M_{zr}, G_{ar}, T_{zrr'}, P_{dfr}^d, P_{fr}^h \geq 0
$$

Most indices used in objective function A.0 are elements of subsets of sets S^r, S^i, S^j. and S^k. These sets refer to the set of regions, activities, netputs (inputs and outputs) and fixed inputs respectively. The indices in objective function A.0 are defined as follows, r regions where $r \in S^r$, i activities where $i \in S^i$, d dairy cow activities where $d \in S^d$ and $S^d \subset S^i$, y outputs, excluding young animals, roughage and manure where $y \in S^y$ and $S^y \subset S^j$, l inputs, excluding young animals, roughage, manure and nutrients (nitrogen (N) and phosphorus (P)) from animal manure and mineral fertilizers where $l \in S^l$ and $S^l \subset S^j$, f nutrients (nitrogen (N) and phosphorus (P)) from animal manure and mineral fertilizers where $f \in S^f$ and $S^f \subset S^j$, z intra-sectorally produced inputs young animals, roughage and manure where $z \in S^z$ and $S^z \subset S^j$, a represents different types of animal manure where $a \in S^a$ and $S^a \subset S^j$. The endogenous variables, written with upper case and the exogenous variables, written with lower case are defined as follows:

$Z =$ total surplus (producer surplus plus consumer surplus) (1000 €)

$Q_{yr} =$ total (domestic and export) demand of agricultural product y in region r (1000 tonnes)

$X_{ir} =$ agricultural activity i in region r (1000 ha; 1000 head)

$M_{zr} =$ import of intra-sectorally produced input z in region r *(1000 head, 1000 m^3; 1000 kVEM*[38]*)*

$E_{zr} =$ export of intra-sectorally produced input z in region r *(1000 head;1000 m^3;1000 kVEM)*

$T_{zrr'} =$ transport of intra-sectorally produced input z from region r to region r' *(1000 m^3; 1000 head)*

$A_{iar} =$ application of animal manure a to activity i in region r *(1000 m^3)*

$F_{ifr} =$ application of nutrients from mineral fertilizer f to activity i in region r *(1000 kg)*

$G_{ar} =$ processing of animal manure a in region r *(1000 m^3)*

$P^d_{dfr} =$ total nutrients surplus f from nutrients bookkeeping system (MINAS) for dairy cow activity d in region r (1000 kg)

$P^h_{fr} =$ nutrients surplus f from nutrients bookkeeping system (MINAS) for the group of remaining grassland and fodder maize activities in region r (1000 kg)

[38] VEM (Voeder Eenheid Melk, fodder unit milk) is a Dutch measure for the amount of energy in feed products: 1VEM = 6.9 kJ Net Energy for Lactation.

p_{fr} = price of mineral fertilizer *f* in region *r* (€ per kg)

$prem_{ir}$ = EU direct payment for activity *i* in region *r* (€ per ha; € per head)

p_a^g = costs of large scale processing of animal manure type *a* (€ per m^3)

p_{zr}^i = import price of intra sectorally produced input *z* in region *r* (€ per head; € per m^3; € per kVEM)

p_{zr}^e = export price of intra sectorally produced input *z* in region *r* (€ per head; € per m^3; € per kVEM)

vc_z = variable transportation costs of intra sectorally produced input *z* (€ per km per m^3; € per km per head)

fc_z = fixed transportation costs of intra sectorally produced input *z* (€ per m^3; € per head)

c_{iar} = application costs of animal manure *a* to activity *i* in region *r* (€ per m^3)

p_f^p = levy on nutrients surplus *f* (€ per kg)

ω_{yr} And ε_{yr} are parameters of the consumers utility function and kk_{ir}, α_{ir} and β_{ir} are parameters of the producers costs function. The first element at the right hand side of objective function A.0 maximizes utility of consumers. The derivation of the parameters of the utility function and the corresponding inverse linear demand function is given in Appendix E. The second element is a quadratic function of total variable cost, excluding costs of intra-sectorally produced inputs (animal manure, young animals and roughage) and mineral fertilizer. Parameters of this function are derived from the PMP approach. This approach is explained in detail in Appendix D. The third element of restriction A.0 contains the costs of mineral fertilizers. The application of nutrients from mineral fertilizers and/or animal manure per activity is determined by the activity and regional specific nutrients balance. Hence, the use of mineral fertilizers per activity is determined endogenously within the model. The nutrients balance is explained below. Prices of inputs, e.g. mineral fertilizers, are exogenous. Prices of inputs and outputs can be different per region to take into account possible differences in quality and farm size and transport cost.

The fourth element gives EU direct payments to agricultural activities under the European Common Agricultural Policy (CAP). With respect to acreage premiums, the Netherlands is divided into two regions; a region with relatively high yields per hectare and a region with relatively low yields per hectare. Regions with higher yields per hectare receive a higher premium per hectare (Post and Silvis, 1998; de Bont, van Everdingen and van Leeuwen, 1999).

The fifth element gives the application costs of animal manure based on contract work. The application costs per unity can be different per activity, manure type and region. The manure application technique on grassland is different compared to techniques used to apply animal manure to uncovered arable land, resulting in costs differences. On arable land the manure can be applied before (or shortly after) planting or after harvesting. Regional differences occur due to differences in soil type. Different technologies are needed to apply manure on heavy clayey soils compared to the sandy soils. This is especially important when manure is applied during periods of heavy rainfall in spring and autumn. The largest application costs differences however exist between slurry (semi-liquid manure) and fixed manure like manure from poultry (Baltussen et al., 1990).

The sixth element of the objective function gives revenues from exports of intra-sectorally produced inputs: roughage, young animals and manure. The seventh element calculates the import costs of intra-sectorally produced inputs. Regional import and export prices are assumed to take into account differences in transportation costs from the region to the national border. For all intra-sectorally produced inputs, regional import prices are higher than regional export prices. This is done to assure that all imported intra-sectorally produced inputs are used by the domestic agricultural activities and not exported again.

The eight element of the objective function gives total costs of possible large scale processing of animal manure. Costs per unit depend on manure type. The ninth element of the objective function calculates regional transport costs of intra-sectorally produced inputs. It is assumed that roughage is not traded between regions. Transport costs of animal manure consist of a variable element related to the transport distance and a fixed element per unit. Due to a lack of data, transport costs of young animals (calves, piglets and one day chickens) only consist of a fixed element per unit.

The tenth and eleventh elements refer to the period after MINAS is introduced. MINAS is effective for farmers with more than 2.5 Livestock Units (LU) per hectare from 1998 onwards and therefore not used in the base (1996). The tenth and eleventh elements of the objective function give MINAS levies paid for nutrients surpluses above acceptable nutrients losses (Ministry of Agriculture, Nature Management and Fishery, 2000 and 2001). Variable P^{d}_{dfr} gives total MINAS nutrient surplus per type of dairy cow. Variable P^{h}_{fr} gives total MINAS nutrient surplus for the group of remaining grassland and fodder maize activities. Again, in the base the latter two variables are of course zero.

Product balance

Restriction A.1 gives the demand or sales of agricultural products. This should be less than or equal to supply of agricultural products delivered by agricultural activities. The variable π^{1}_{yr} is the shadow price of agricultural product *y* in region *r* (€ per ton) and gives the increase in the objective function if agricultural production could increase marginally. The shadow price of the product balance A.1 equals the market price of product *y* in region *r*.

$$Q_{yr} \leq \sum_{i} \gamma_{iyr} X_{ir} \qquad \forall y,r \qquad \left[\pi^{1}_{yr}\right] \qquad \text{A.1}$$

Where:

γ_{iyr} = output *y* per activity *i* in region *r* (1000 kg per ha; 1000 kg per head)

Young animals balances

Calves, piglets and eggs are produced in the own region, imported from other regions or imported from the rest of the world. They are also used in the agricultural sector in the own region, exported to other regions in the Netherlands or exported to the rest of the world. Young animals balances are given by:

$$-\overbrace{\sum_i \gamma_{isr} X_{ir}}^{1} + \overbrace{\sum_i w_{isr} X_{ir}}^{2}$$

$$-\overbrace{M_{sr}}^{3} + \overbrace{E_{sr}}^{4} - \overbrace{\sum_{r'} T_{sr'r} + \sum_{r'} T_{srr'}}^{5} = 0 \qquad \forall s, r \qquad \left[\pi^2_{sr}\right] \qquad \text{A.2}$$

Where:

w_{isr} = input *s* per activity *i* in region *r* (kg per ha; kg per head; € per ha; € per head; head per head)

The new index *s* represents young animals where $s \in S^s$ and $S^s \subset S^j$. Regional shadow prices of young animals are given by π^2_{sr}. This variable shows the increase in the objective function if the input (young animals) could be made less restrictive marginally and equals domestic market prices. The first element of the young animals balance gives yearly regional production of different types of young animals. The second element calculates yearly regional use of young animals as an input to animal activities. The third element consists of imports of young animals. The fourth element consists of exports of young animals. The fifth element gives the interregional net-import or net-export of young animals.

Roughage balances

A large part of the agricultural area in the Netherlands is allocated to grassland and fodder maize. Therefore the roughage balance at the regional level is an important element of DRAM. Feeding rations of beef cattle and dairy cows consist of roughage and concentrates. DRAM assumes that concentrates are available in unlimited amounts at exogenous prices. Furthermore, DRAM assumes that roughage is produced and consumed within the own region. That is, roughage is not transported between regions because of the relative high transport costs. However, both grass and maize can be imported and exported from the rest of the world as rest of the world includes use and produce of grass and maize by activities in the own region not covered by DRAM (horses, goats, sheeps, small farms not accounted for in agricultural census, etc.).

Two qualities of roughage are produced namely grass and maize silage. The roughage balances are given by:

$$-\overbrace{\sum_i \gamma_{iur} X_{ir}}^{1} + \overbrace{\sum_i w_{iur} X_{ir}}^{2} - \overbrace{M_{ur}}^{3} + \overbrace{E_{ur}}^{4} = 0 \qquad \forall u,\, r \qquad \left[\pi^3_{ur}\right] \qquad \text{A.3}$$

The new index u represents roughage products (grass and maize silage) where $u \in S^u$ and $S^u \subset S^j$. Regional shadow prices of roughage are given by π^3_{ur} and equal domestic market prices. The first element calculates the regional production of roughage product u. Fodder maize and grass is produced by the dairy cows and by the remaining grassland and fodder maize activities. The second element consists of the consumption of roughage product u. The third and fourth element consists of the imports and the exports of roughage products respectively.

Manure balances

Supply of animal manure is a function of number of animals, excretion per animal and fraction of total excretion per animal that is produced in animal sheds. Regional manure supply can be used in the own region (including large scale processing of animal manure), transported to other regions in the Netherlands or exported to the rest of the world. The manure balances are given by:

$$-\overbrace{\sum_i \gamma_{iar} X_{ir}}^{1} + \overbrace{\sum_i A_{iar}}^{2} + \overbrace{AF_{ar}}^{3} + \overbrace{G_{ar}}^{4}$$

$$-\overbrace{M_{ar}}^{5} + \overbrace{E_{ar}}^{6} - \overbrace{\sum_{r'} T_{ar'r} + \sum_{r'} T_{arr'}}^{7} = 0 \qquad \forall a,\, r \qquad \left[\pi^{4a}_{ar}\right] \qquad \text{A.4a}$$

Where the variable AF_{ar} represents excretion of manure in the field during pasturing. The first element of restriction A.4a consists of total animal manure production including production in animal sheds and in the field during pasturing for a specific manure type. The second element consists of the regional application to the crop activities. The third element gives manure excretion in the field during pasturing. The fourth element gives the amount of manure that is available for large scale processing. The fifth and sixth element of restriction A.4a consists of the imports and exports of animal manure to the rest of the world respectively. The seventh element calculates interregional net-import or net-export of animal manure.

Manure excretion in the field only occurs through grazing dairy cows in DRAM. It is assumed that other animals produce all the manure in animal sheds and nothing in the field. Moreover, excretion of manure in the field during pasturing equals a fixed percentage of total manure excretion per dairy cow. This can be written as follows:

$$\overbrace{\sum_i \gamma_{iar}(1-\delta_{ir})X_{ir}}^{1} - \overbrace{AF_{ar}}^{2} = 0 \qquad \forall a, r \qquad \left[\pi_{ar}^{4b}\right] \qquad \text{A.4b}$$

Where the coefficient δ_{ir} represents excretion of manure in animal sheds as a fraction of total excretion per animal per year and π_{ar}^{4b} equals the shadow price of animal manure produced in the field. Restriction A.4b can be included in restriction A.4a to reach the following restriction, which is used in DRAM:

$$-\overbrace{\sum_i \gamma_{iar}\delta_{ir}X_{ir}}^{1} + \overbrace{\sum_i A_{iar}}^{2} + \overbrace{G_{ar}}^{3}$$

$$-\overbrace{M_{ar}}^{4} + \overbrace{E_{ar}}^{5} - \overbrace{\sum_{r'} T_{ar'r} + \sum_{r'} T_{arr'}}^{6} = 0 \qquad \forall a, r \qquad \left[\pi_{ar}^{4}\right] \qquad \text{A.4}$$

Where π_{ar}^{4} is the shadow price of animal manure.

Fertilization requirements

Animal manure produced by livestock activities contains nutrients that can be used to meet fertilization requirements of the field and arable crops. Another source of fertilizer is nutrients from mineral fertilizer. Fertilization requirements in DRAM are modeled as:

$$\overbrace{w_{ifr}X_{ir}}^{1} - \overbrace{\sum_a \psi_{afr}\chi_{iafr}^{a}A_{iar}}^{2} - \overbrace{F_{ifr}}^{3} \le 0 \qquad \forall i,f,r \qquad \left[\pi_{ifr}^{5}\right] \qquad \text{A.5}$$

Where:

w_{ifr} = requirement of nutrient *f* by activity *i* in region *r* (kg per ha, kg per head)

ψ_{afr} = content of nutrient *f* per animal manure type *a* in region *r*, after correction of emission of nitrogen as ammonia (NH_3) in animal sheds and storage (kg per m^3)

χ^{a}_{iafr} = workability coefficient of nutrient *f* in animal manure type *a* applied to activity *i* in region *r* (fraction)

Regional and activity specific shadow prices of nutrients are given by π^{5}_{ifr} (€ per kg). The first element of restriction A.5 consists of the fertilization requirements of agricultural activities. To fulfill the fertilization requirements given by the first element of restriction A.5, it is assumed that both animal manure and mineral fertilizers can be used. The second element of restriction A.5 gives the amount of nutrients from animal manure in mineral fertilizer equivalents. Animal manure contains organic and mineral nitrogen and their share in total nitrogen content differs for different types of animal manure. This is important because organic nitrogen and mineral nitrogen are different with respect to their workability. The workability coefficient of nitrogen in animal manure is an exogenous variable and depends on the type of animal, the crop where the animal manure is applied to and the moment of application. Regional differences in workability due to differences in soil type and moment of application are also taken into account (Van Staalduinen et al., 2001). The third element of restriction A.5 consists of the use of nutrients from mineral fertilizer per activity. Note that it is assumed that manure excretion in the field during pasturing does not contribute to fertilization requirements.

Maximum acceptation of animal manure

Restriction A.5 allows applying more nutrients from animal manure than the corresponding fertilization requirements per crop. Mineral fertilizer will only be used to fill the gap between nutrients from animal manure in mineral fertilizer equivalents and the fertilization requirements.

Application of animal manure is restricted in DRAM by a maximum acceptation of animal manure. When modeling animal manure acceptation it was recognized that fertilization behavior of farms is based on the whole cropping plan and behavior could be different per farm type. Especially at arable farms application of animal manure has its limitations. These are related to the effects of animal manure on crop growth and quality.

Dairy farms are represented by different type of dairy cow activities in DRAM. For every dairy cow activity in the model the following restriction is included to model maximum acceptation of animal manure:

$$\overbrace{\sum_a \psi_{afr} A_{dar}}^{1} + \overbrace{\sum_a \gamma_{dar}(1-\delta_{dr})\psi^{p}_{afr} X_{dr}}^{2} - \overbrace{\upsilon_{dfr} X_{dr}}^{3} \leq 0 \qquad \forall d,f,r \qquad \left[\pi^{6a}_{dfr}\right] \qquad \text{A.6a}$$

Where d is a dairy cow activity and $d \in S^d$ and $S^d \subset S^i$. Regional shadow prices are given by π^{6a}_{dfr} (€ per kg) and give the increase in the objective function if acceptation of nutrients from animal manure could be made less restrictive marginally. In restriction A.6a variable υ_{dfr} is defined as the maximum amount of nutrients from animal manure that dairy farmers are willing to accept (kg per dairy cow activity)[39]. The first element of restriction A.6a gives the total use of nutrients from animal manure per dairy cow activity per region. The second element gives the total production of nutrients from animal manure in the field by grazing dairy cows. The third element gives the total maximum acceptation of nutrients from animal manure per dairy cow activity per region.

For the group of arable crops, vegetables in the open and flower bulbs the restriction on acceptation of animal manure is as follows:

$$\overbrace{\sum_a \sum_b \psi_{afr} A_{bar}}^{1} - \overbrace{\sum_b \upsilon_{bfr} X_{br}}^{2} \leq 0 \qquad \forall f,r \qquad \left[\pi^{6b}_{fr}\right] \qquad \text{A.6b}$$

[39] It should be noted that the manure acceptation per agricultural activity is an exogenous variable in DRAM. In reality manure acceptation is among other things a function of prices of animal manure.

Where the new index b is an arable activity and $b \in S^b$ and $S^b \subset S^i$. Regional shadow prices are given by π_{fr}^{6b} (€ per kg) and give the increase in the objective function if acceptation of nutrients from animal manure could be made less restrictive marginally. In restriction A.6b variable υ_{bfr} is defined as the maximum quantity of nutrients from animal manure that arable farmers are willing to accept per crop activity (kg per hectare). The first element of restriction A.6b gives the total use of nutrients from animal manure over all arable crops. The second element gives the maximum acceptation of nutrients from animal manure over all arable crops.

For the group of remaining grassland and fodder maize activities the restriction on acceptation of animal manure is:

$$\overbrace{\sum_a \sum_h \psi_{afr} A_{har}}^{1} - \overbrace{\sum_h \upsilon_{hfr} X_{hr}}^{2} \le 0 \qquad \forall f,r \qquad \left[\pi_{fr}^{6c} \right] \qquad \text{A.6c}$$

Where the new index h is a grassland or fodder maize activity[40] and $h \in S^h$ and $S^h \subset S^i$. Regional shadow prices are given by π_{fr}^{6c} (€ per kg) and give the increase in the objective function if acceptation of nutrients from animal manure could be made less restrictive marginally. In restriction A.6c variable υ_{hfr} is defined as the maximum acceptation of animal manure per activity (kg per hectare). The first element of restriction A.6c gives the total use of nutrients from animal manure over remaining grassland and fodder maize activities per region. The second element gives the maximum acceptation of nutrients from animal manure over remaining grassland and fodder maize activities per region.

Export balance animal manure

Restriction A.7 puts an upper limit on exports of animal manure to the rest of the world. This upper limit can be defended because the potential export market for animal manure may be rather small. This is caused by relative high transport costs and possible sanitary and phyto sanitary requirements.

[40] The difference between the index h and u (used in restriction A.3) is that index h refers to an activity whereas the index u refers to a product (commodity).

$$\sum_r E_{ar} - \phi_a \leq 0 \qquad \forall \text{ a} \qquad \left[\pi_a^7\right] \qquad \text{A.7}$$

National shadow prices of the maximum manure export are given by π_a^7. In restriction A.7, ϕ_a represents the maximum exports of animal manure (1000 m^3). No limitations are put on the import and export of other intra-sectorally produced inputs (roughage and young animals).

Fixed inputs

Fixed inputs included in DRAM are agricultural land and quotas. The regional agricultural land balance equals:

$$\sum_i \sigma_{imr} X_{ir} - \kappa_{mr} \leq 0 \qquad \forall m, r \qquad \left[\pi_{mr}^8\right] \qquad \text{A.8}$$

The new index *m* represents agricultural land where $m \in S^m$ and $S^m \subset S^k$. Variable κ_{mr} is agricultural land per region (1000 ha), σ_{imr} is use of agricultural land per activity per region (ha per ha; ha per head). Regional shadow prices of agricultural land are given by π_{mr}^8.

Regional sugar beet quotas are given by:

$$\sum_i \sigma_{inr} X_{ir} - \kappa_{nr} \leq 0 \qquad \forall n, r \qquad \left[\pi_{nr}^9\right] \qquad \text{A.9}$$

The new index *n* represents sugar beets where $n \in S^n$ and $S^n \subset S^k$. The variable κ_{nr} represents regional quotas for sugar beets (1000 tonnes), σ_{inr} is use of sugar beet quota per activity per region (ton per ha). Regional shadow prices of sugar beet quotas are given by π_{nr}^9. No distinction between A, B and C quota is included.

Quotas for milk and starch potatoes are included at the national level:

$$\sum_i \sum_r \sigma_{iqr} X_{ir} - \sum_r \kappa_{qr} \leq 0 \qquad \forall q \qquad \left[\pi_q^{10}\right] \qquad \text{A.10}$$

The new index *q* represents starch potatoes and milk quotas where $q \in S^q$ and $S^q \subset S^k$. The variable κ_{qr} represents regional allocation of national quotas for milk and starch potatoes in the base period (1000 tonnes). σ_{ibr} is use of starch potatoes and milk quota per activity per region (1000 kg per ha, 1000 kg per head respectively). National shadow prices of quotas for starch potatoes and milk are given by π_q^{10}.

Dutch manure and nutrients policy in base period (1996)

When modeling manure application standards in the base period (1996) it was again taken into account that behavior could be different per farm type. Dairy farms are represented by different type of dairy cow activities in DRAM. For every dairy cow activity in the model the following restriction is included to model manure application standards in the base period:

$$\overbrace{\sum_a \psi_{afr} A_{dar}}^{1} + \overbrace{\sum_a \gamma_{dar}(1-\delta_{dr})\psi_{afr}^{p} X_{dr}}^{2} - \overbrace{\theta_{dfr} X_{dr}}^{3} \leq 0 \qquad \forall d,f,r \qquad \left[\pi_{dfr}^{11a}\right] \qquad \text{A.11a}$$

Variable π_{dfr}^{11a} gives the shadow price of the restriction on manure application (€/kg). This shadow price shows the increase in the objective value, as the standard on manure application would increase marginally. The variable θ_{dfr} gives the manure application standard in nutrients from animal manure (kg per dairy cow activity) and variable ψ_{afr}^{p} gives the nutrients content of animal manure produced in the field by grazing dairy cows (kg per m^3). The first term of restriction A.11a gives the total application of nutrients from animal manure per dairy cow activity per region (1000 kg). The second term gives the total quantity of nutrients that is produced in the field by grazing dairy cows (1000 kg). The third term gives the legal quantity of nutrients from animal manure that can be applied (1000 kg). The manure application standards are different for grassland and arable crops, including fodder maize. Hence, the manure application standard per dairy cow activity depends on the hectares of grassland and fodder maize per dairy cow activity. Note that the only difference between restriction A.6a and A.11a is that in the former restriction the application of nutrients from animal manure is restricted by (technical) acceptation limits, while in the later restriction the application of nutrients from animal manure is restricted by standards from manure policies in the base period (1996).

The following restriction on application of animal manure is applied to the group of arable crops, vegetables in the open and flower bulb activities:

$$\overbrace{\sum_a \sum_b \psi_{afr} A_{bar}}^{1} - \overbrace{\sum_b \theta_{bfr} X_{br}}^{2} \leq 0 \qquad \forall f,r \qquad \left[\pi_{fr}^{11b}\right] \qquad \text{A.11b}$$

Variable π_{fr}^{11b} gives nutrient and regional specific shadow prices of the restriction on manure application over all arable crops (€/kg). As before, the first term of restriction A.11b gives the total application of nutrients from animal manure over all arable crops (1000 kg). The second term gives the legal quantity of animal manure that can be applied to the group of arable crops (1000 kg).

The following restriction on application of animal manure is included to represent the group of remaining grassland and fodder maize activities:

$$\overbrace{\sum_a \sum_h \psi_{afr} A_{har}}^{1} - \overbrace{\sum_h \theta_{hfr} X_{hr}}^{2} \leq 0 \qquad \forall f,r \qquad \left[\pi_{fr}^{11c}\right] \qquad \text{A.11c}$$

Variable π_{fr}^{11c} gives nutrient and regional specific shadow prices of the restriction on manure application on the group of remaining grassland and fodder maize activities (€/kg). As before, the first term of restriction A.11c gives the total application of nutrients from animal manure (1000 kg). The second term gives the legal quantity of animal manure that can be applied to the group of remaining grassland and fodder maize activities (1000 kg).

Dutch manure and nutrients policy after 1998

In 2001 MINAS became compulsory for all farmers including arable farmers and other open-field producers. Moreover, in 2002 a system of manure contracts, known as MAO, was introduced. MINAS and MAO are modeled per group of activities. The different groups are discussed before. Per dairy cow activity MINAS is modeled as:

$$\overbrace{\sum_a \psi_{afr} A_{dar}}^{1} + \overbrace{F_{dfr}}^{2} + \overbrace{\sum_a \gamma_{dar} (1-\delta_{dr}) \psi_{afr}^{p} X_{dr}}^{3}$$

$$-\overbrace{(\gamma_{dfr} + \tau_{dfr}) X_{dr}}^{4} + \overbrace{\zeta_{dfr} X_{dr}}^{5} - \overbrace{P_{dfr}^{d}}^{6} \leq 0 \qquad \forall d,f,r \qquad \left[\pi_{dfr}^{12a}\right] \qquad \text{A.12a}$$

The shadow price of restriction A.12a is given by π_{dfr}^{12a} (€/kg) and gives the increase in the objective function if MINAS per dairy cow activity becomes less restrictive marginally. Variable γ_{dfr} is the uptake of nutrients (kg per head). Per type of dairy cow it represents the uptake of nutrients per hectare of grassland and fodder maize divided by the number of dairy cows per hectare of grassland and fodder maize. Variable τ_{dfr} represents the threshold level for acceptable nutrients loss, also in kg per head, taking into account differences in threshold levels for grassland and fodder maize and hectare of grassland and fodder maize per dairy cow activity. Variable ζ_{dfr}, in kg per head, is a correction factor to correct for relative high threshold levels for nutrients surpluses on grassland. The correction factor ζ_{dfr} is calculated as 2 livestock units (LU)[41] per hectare grassland times the difference between nutrients in manure in total and nutrients in manure per dairy cow. The first element in restriction A.12a contains again the total use of nutrients from animal manure per type of dairy cow activity. The second term gives the nutrients from mineral fertilizers per type of dairy cow activity. The third term gives the quantity of nutrients from animal manure that is produced in the field per type of dairy cow. Here variable ψ^{p}_{afr} is the nutrient content of animal manure produced in the field by grazing dairy cows (kg per m^3). The fourth term represents the total nutrients uptake and threshold levels per type of dairy cow activity. The fifth term gives the correction for relative high acceptable nutrient losses per hectare grassland as explained above. The sixth term gives the MINAS nutrient surplus over which a MINAS levy has to be paid (P^{d}_{dfr}).

For the group of arable crops, vegetables in the open and flower bulb activities MINAS is modeled as:

$$\overbrace{\sum_a \sum_b \psi_{afr} A_{bar}}^{1} + \overbrace{\sum_b F_{bfr}}^{2} - \overbrace{\sum_b (\gamma_{bfr} + \tau_{bfr}) X_{br}}^{3} \leq 0 \qquad \forall f,r \qquad \left[\pi^{12b}_{fr}\right] \qquad \text{A.12b}$$

Variable π^{12b}_{fr} is the shadow price for this restriction and gives the increase in the objective function if MINAS would be less restrictive marginally for the group of arable crops, vegetables in the open and flower bulb activities. The first term of restriction A.12b gives the total application of animal manure over all arable crops per region, the second term gives the total application of mineral fertilizer over all arable crops per region and the third term gives the total uptake of nutrients by harvested crops plus the total nutrients threshold levels over all arable crops. Note that

[41] 1 dairy cow is equal to 1 livestock unit (LU).

restriction A.12b does not include a variable accounting for a possible nutrients surplus above the threshold level as it is assumed that this variable is zero at the average arable farm. Off course this can be different for individual farms.

For the group of remaining grassland and fodder maize activities MINAS is modeled as:

$$\overbrace{\sum_a \sum_h \psi_{afr} A_{har}}^{1} + \overbrace{\sum_h F_{hfr}}^{2} - \overbrace{\sum_h (\gamma_{hfr} + \tau_{hfr}) X_{hr}}^{3}$$

$$+ \overbrace{\sum_h \zeta_{hfr} X_{hr}}^{4} - \overbrace{P_{fr}^{h}}^{5} \leq 0 \qquad \forall f,r \qquad \left[\pi_{fr}^{12c}\right] \qquad \text{A.12c}$$

Variable π_{fr}^{12c} is the shadow price of restriction A.12c and gives the increase in the objective function if MINAS would be less restrictive marginally for the group of remaining grassland and fodder maize activities. The MINAS balance for the remaining grassland and fodder maize activity group also includes the nutrients correction factor related to the remaining grassland activity (kg per hectare). Variable P_{fr}^{h} in restriction A.12c gives the total nutrients surplus above the threshold level (1000 kg). The first term of restriction A.12c gives the total application of animal manure over the group of remaining grassland and fodder maize activities per region, the second term gives the total application of mineral fertilizer per region, the third term gives the uptake of nutrients by harvested crops plus the nutrients threshold levels, the fourth term is the correction factor related to grassland and the fifth term of restriction A.12c gives the total MINAS nutrients surplus above the nutrients surplus threshold level over the remaining grassland and fodder maize activities.

Modeling the MAO system is very similar to modeling manure acceptation (see restrictions A.6a to A.6c) and manure application standards (see restrictions A.11a to A.11c). For every dairy cow activity in the model the following restriction is included to represent the MAO system:

$$\overbrace{\sum_a \psi_{afr}^{m} A_{dar}}^{1} + \overbrace{\sum_a \gamma_{dar} (1-\delta_{dr}) \psi_{afr}^{m} X_{dr}}^{2} - \overbrace{\theta_{dfr}^{m} X_{dr}}^{3} \leq 0 \qquad \forall d,f,r \qquad \left[\pi_{dfr}^{13a}\right] \qquad \text{A.13a}$$

Variable π^{13a}_{dfr} gives the shadow price of the MAO restriction on manure application (€/kg). This shadow price shows the increase in the objective value if MAO would be less restrictive marginally. Variable ψ^{m}_{afr} gives the nutrients content of animal manure based on normalized figures from MAO (kg per m^3), taking into account that only 85% of the fixed manure and nutrients production has to be contracted. Variable θ^{m}_{dfr} gives the manure application standard under MAO (kg N per dairy cow activity). The first term of restriction A.13a gives the total application of nutrients from animal manure per dairy cow activity per region (1000 kg). The second term gives the total quantity of nutrients that is produced in the field by grazing dairy cows (1000 kg). The third term gives the legal quantity of nutrients from animal manure that can be applied per dairy cow activity per region (1000 kg).

The following restriction on application of animal manure is included over all arable crops:

$$\overbrace{\sum_a \sum_b \psi^{m}_{afr} A_{bar}}^{1} - \overbrace{\sum_b \theta^{m}_{bfr} X_{br}}^{2} \leq 0 \qquad \forall f,r \qquad \left[\pi^{13b}_{fr}\right] \qquad \text{A.13b}$$

Variable π^{13b}_{dfr} gives nutrient and regional specific shadow prices of the MAO restriction on manure application over all arable crops (€/kg). As before, the first term of restriction A.13b gives the total application of nutrients from animal manure over all arable crops (1000 kg). The second term gives the legal quantity of animal manure that can be applied over all arable crops (1000 kg).

The following restriction on application of animal manure is included for the group of remaining grassland and fodder maize activities:

$$\overbrace{\sum_a \sum_h \psi^{m}_{afr} A_{har}}^{1} - \overbrace{\sum_h \theta^{m}_{hfr} X_{hr}}^{2} \leq 0 \qquad \forall f,r \qquad \left[\pi^{13c}_{fr}\right] \qquad \text{A.13c}$$

Variable π^{13c}_{fr} give nutrient and regional specific shadow prices of the MAO restriction on manure application over the group of remaining grassland and fodder maize activities (€/kg). As before, the first term of restriction A.13c gives the total application of nutrients from animal manure over the group of remaining grassland and fodder maize activities (1000 kg). The second term gives the legal quantity of animal manure that can be applied over the group of remaining grassland and fodder maize activities (1000 kg).

Appendix B Detailed mathematical presentation of DRAM, the dual NLP model[42]

Introduction

The primal model shows how input quantities are related to output quantities. The dual model gives insights into how (shadow) prices of inputs are related to (shadow) prices of outputs. In this appendix we give the dual model corresponding to the primal model described in Appendix A.

The dual objective function

$$\min \text{TC} = \overbrace{0.5\varepsilon_{yr}Q_{yr}^2}^{1} + \overbrace{\sum_a \pi_a^7 \phi_a}^{2} \qquad \text{B.1}$$

$$+ \overbrace{\sum_m \sum_r \pi_{mr}^8 \kappa_{mr}}^{3} + \overbrace{\sum_n \sum_r \pi_{nr}^9 \kappa_{nr}}^{4} + \overbrace{\sum_q \sum_r \pi_q^{10} \kappa_{qr}}^{5} + \overbrace{\sum_i \sum_r (0.5\beta_{ir} X_{ir}^2 - kk_{ir})}^{6}$$

$$\pi_a^7, \pi_{mr}^8, \pi_{nr}^9, \pi_q^{10} \geq 0$$

Where:

π_a^7 = shadow price of animal manure export, see restriction A.7 (€ per m^3)

π_{mr}^8 = shadow price of agricultural land in region r, see restriction A.8 (€ per ha)

π_{nr}^9 = shadow price of sugar beet quotas in region r, see restriction A.9 (€ per ton)

π_q^{10} = shadow price of starch potatoes and milk quotas, see restriction A.10 (€ per ton)

Given the primal problem presented in Appendix B, the dual problem can be derived from the classical Lagrangean function and applying the Kuhn-Tucker conditions. The objective function of the dual problem is given by restriction B.1. In restriction B.1

[42] I would like to thank Quirino Paris for his very helpful comments on an earlier version of this Appendix. Any remaining error is off course my own responsibility.

TC is defined as the shadow costs (1000 €), which has to be minimized. The first and sixth element of B.1 result from the quadratic (and constant) terms in the objective function of the primal problem. The second element represents shadow costs that come into existence because of the restricted manure exports to the rest of the world. The shadow price π_a^7 is nonzero and positive in case the manure export restriction is binding and can be seen as a rent passed on to exporters of animal manure. A rent comes into existence because the export price of animal manure is higher than the domestic (shadow) price of animal manure. Through the export quota, the domestic price of animal manure is decoupled from prices in the rest of the world. The third, fourth and fifth elements represent total shadow costs of fixed inputs land and quotas.

Equilibrium conditions

Dairy cow activities

$$\overbrace{\alpha_{ir} + \beta_{ir} X_{ir}}^{1} + \overbrace{\sum_s \pi_{sr}^2 (-\gamma_{isr} + w_{isr})}^{2}$$

$$+ \overbrace{\sum_u \pi_{ur}^3 (-\gamma_{iur} + w_{iur})}^{3}$$

$$- \overbrace{\sum_a \pi_{ar}^4 \gamma_{iar} \delta_{iar}}^{4} + \overbrace{\sum_f \pi_{ifr}^5 w_{ifr}}^{5}$$

$$+ \overbrace{\sum_a \sum_f \pi_{ifr}^{6a} (\gamma_{iar} (1 - \delta_{ir}) \psi_{afr}^p)}^{6}$$

$$- \overbrace{\sum_f \pi_{ifr}^{6a} \upsilon_{ifr}}^{7} + \overbrace{\sum_m \pi_{mr}^8 \sigma_{imr}}^{8} + \overbrace{\sum_q \pi_q^{10} \sigma_{iqr}}^{9}$$

Manure policy in base period

$$+ \overbrace{\sum_a \sum_f \pi_{ifr}^{11a} (\gamma_{iar} (1 - \delta_{ir}) \psi_{afr}^p)}^{10} - \overbrace{\sum_f \pi_{ifr}^{11a} \theta_{ifr}}^{11}$$

Manure policy after 1998 (MINAS and MAO)

$$+ \overbrace{\sum_a \sum_f \pi_{ifr}^{12a} (\gamma_{iar} (1 - \delta_{ir}) \psi_{afr}^p)}^{12} - \overbrace{\sum_f \pi_{ifr}^{12a} (\gamma_{ifr} + \tau_{ifr})}^{13}$$

$$+ \overbrace{\sum_a \sum_f \pi_{ifr}^{13a} (\gamma_{iar} (1 - \delta_{ir}) \psi_{afr}^m)}^{14} - \overbrace{\sum_f \pi_{ifr}^{13a} \theta_{ifr}^m}^{15} \geq \sum_y \pi_{yr}^1 \gamma_{iyr} + prem_{ir} \quad \forall\ i, r \qquad \text{B.2a}$$

$$\pi^{1}_{yr}, \pi^{5}_{ifr}, \pi^{6a}_{ifr},\ \pi^{8}_{lr}, \pi^{9}_{br}, \pi^{10}_{q},\ \pi^{11a}_{ifr},\ \pi^{12a}_{ifr}, \pi^{13a}_{ifr} \geq 0$$

$$\pi^{2}_{sr}, \pi^{3}_{ur}, \pi^{4}_{ar} \ \textit{are free}$$

Intensive livestock activities, including beef cattle

$$\overbrace{\alpha_{ir} + \beta_{ir} X_{ir}}^{1} + \overbrace{\sum_{s} \pi^{2}_{sr} (-\gamma_{isr} + w_{isr})}^{2}$$

$$+ \overbrace{\sum_{u} \pi^{3}_{ur} w_{iur}}^{3} - \overbrace{\sum_{a} \pi^{4}_{ar} \gamma_{iar} \delta_{iar}}^{4} \quad \geq \quad \sum_{y} \pi^{1}_{yr} \gamma_{iyr} + prem_{ir} \quad \forall\ i, r \qquad \text{B.2b}$$

$$\pi^{1}_{yr} \geq 0$$

$$\pi^{2}_{sr}, \pi^{3}_{ur}, \pi^{4}_{ar} \ \textit{are free}$$

Arable crops, including vegetables in the open and flower bulbs

$$\overbrace{\alpha_{ir} + \beta_{ir} X_{ir}}^{1} + \overbrace{\sum_{f} \pi^{5}_{ifr} w_{ifr}}^{2} - \overbrace{\sum_{f} \pi^{6b}_{fr} \upsilon_{ifr}}^{3}$$

$$+ \overbrace{\sum_{m} \pi^{8}_{mr} \sigma_{imr}}^{4} + \overbrace{\sum_{n} \pi^{9}_{nr} \sigma_{inr}}^{5} + \overbrace{\sum_{q} \pi^{10}_{q} \sigma_{iqr}}^{6}$$

Manure policy in base period

$$- \overbrace{\sum_{f} \pi^{11b}_{fr} \theta_{ifr}}^{6}$$

Manure policy after 1998 (MINAS and MAO)

$$- \overbrace{\sum_{f} \pi^{12b}_{fr} (\gamma_{ifr} + \tau_{ifr})}^{7} - \overbrace{\sum_{f} \pi^{13b}_{fr} \theta^{m}_{ifr}}^{8} \quad \geq \quad \sum_{y} \pi^{1}_{yr} \gamma_{iyr} + prem_{ir} \quad \forall\ i, r \qquad \text{B.2c}$$

$$\pi^{1}_{yr}, \pi^{5}_{ifr}, \pi^{6b}_{fr},\ \pi^{8}_{lr}, \pi^{9}_{br}, \pi^{10}_{q},\ \pi^{11b}_{fr},\ \pi^{12b}_{fr}, \pi^{13b}_{fr} \geq 0$$

Remaining grassland and fodder maize activities

$$\overbrace{\alpha_{ir} + \beta_{ir} X_{ir}}^{1} + \overbrace{\sum_{f} \pi^{5}_{ifr} w_{ifr}}^{2}$$

$$- \overbrace{\sum_{f} \pi^{6c}_{fr} \upsilon_{ifr}}^{3} + \overbrace{\sum_{m} \pi^{8}_{mr} \sigma_{imr}}^{4}$$

Manure policy in base period

$$-\overbrace{\sum_f \pi_{fr}^{11c}\theta_{ifr}}^{5}$$

Manure policy after 1998 (MINAS and MAO)

$$-\overbrace{\sum_f \pi_{fr}^{12c}(\gamma_{ifr}+\tau_{ifr})}^{6}-\overbrace{\sum_f \pi_{fr}^{13c}\theta_{ifr}^{m}}^{7} \geq \sum_u \pi_{ur}^{3}\gamma_{iur} + prem_{ir} \quad \forall\ i,r \qquad \text{B.2d}$$

$$\pi_{yr}^{1}, \pi_{ifr}^{5}, \pi_{fr}^{6c}, \pi_{lr}^{8}, \pi_{fr}^{11c}, \pi_{fr}^{12c}, \pi_{fr}^{13c} \geq 0$$

$$\pi_{ur}^{3}\ is\ free$$

Where:

π_{sr}^{2} = shadow price of young animals *s* in region *r*, see restriction A.2 (€ per head)

π_{ur}^{3} = shadow price of roughage *u* in region *r*, see restriction A.3 (€ per kVEM)

π_{ar}^{4} = shadow price of animal manure *a* in region *r*, see restriction A.4 (€ per m^3)

π_{ifr}^{5} = shadow price of nutrient *f* used by activity *i* in region *r*, see restriction A.5 (€ per kg)

π_{ifr}^{6a} = shadow price of nutrient *f* per type of dairy cow *i* in region *r* from restricted manure acceptation, see restriction A.6a (€ per kg)

π_{fr}^{6b} = shadow price of nutrient *f* for arable crops in region *r* from restricted manure acceptation, see restriction A.6b (€ per kg)

π_{fr}^{6c} = shadow price of nutrient *f* for remaining grassland and fodder maize activities in region *r* from restricted manure acceptation, see restriction A.6c (€ per kg)

π_{ifr}^{11a} = shadow price of nutrient *f* per type of dairy cow *i* in region *r* from manure application standards in the base, see restriction A.11a (€ per kg)

π_{fr}^{11b} = shadow price of nutrient *f* for arable crops in region *r* from manure application standards in the base, see restriction A.11b (€ per kg)

π_{fr}^{11c} = shadow price of nutrient *f* for remaining grassland and fodder maize activities in region *r* from manure application standards in the base, see restriction A.11c (€ per kg)

π_{ifr}^{12a} = shadow price of nutrient *f* per type of dairy cow *i* in region *r* from MINAS, see restriction A.12a (€ per kg)

π_{fr}^{12b} = shadow price of nutrient *f* for arable crops in region *r* from MINAS, see restriction A.12b (€ per kg)

π_{fr}^{12c} = shadow price of nutrient *f* for remaining grassland and fodder maize activities in region *r* from MINAS, see restriction A.12c (€ per kg)

π_{ifr}^{13a} = shadow price of nutrient *f* per type of dairy cow *i* in region *r* from MAO, see restriction A.13a (€ per kg)

π_{fr}^{13b} = shadow price of nutrient *f* for arable crops in region *r* from MAO, see restriction A.13b (€ per kg)

π_{fr}^{13c} = shadow price of nutrient *f* for remaining grassland and fodder maize activities in region *r* from MAO, see restriction A.13c (€ per kg)

Restrictions B.2a to B.2d are equilibrium conditions known as the First Order Conditions (FOC) of profit maximization. Restrictions B.2a to B.2d are the FOC for dairy cows, intensive livestock activities, arable crops and remaining grassland and fodder maize activities respectively. The FOC says that the marginal costs of activity *i* in region *r* must be greater than or equal to marginal revenue of activity *i* in region r.

The marginal costs per dairy cow activity given by restriction B.2a consists of (many) different elements. The first element gives the marginal costs per activity, excluding marginal costs of intra-sectorally produced inputs (young animals, roughage and manure) and nutrients application. This component of total marginal costs is a linear function of the activity level. The second element gives marginal costs of young animals per dairy cow activity. This is made up of the shadow price of young animals per head multiplied with the net young animals requirement per activity. If this component is negative, production of young animals per activity exceeds utilization of young animals per activity for replacement. The third element gives marginal costs of roughage per dairy cow activity. Again, this is made up of the shadow price of roughage per kVEM multiplied with net roughage requirement per activity. A negative sign means that production per activity exceeds utilization per activity. The fourth element gives marginal costs of animal manure per dairy cow activity, given by the shadow price of animal manure per m^3 times production of animal manure per activity in animal sheds. A positive shadow price of animal manure means an increase in marginal revenue per dairy cow activity. A negative shadow price means an increase in marginal costs per dairy cow activity. The fifth element represents marginal costs of nutrients per dairy cow activity. This is given by the shadow price of nutrients times the nutrients requirement per dairy cow activity. The sixth element shows the marginal costs of manure production in the field by grazing dairy cows, when the restriction on manure acceptation per dairy cow activity is binding. The marginal costs effect occurs because manure that is produced in the field during grazing cannot be transported to other activities or regions. The seventh element shows the rent that is passed on to dairy cow activities if the related manure acceptation restriction is binding. The eight and ninth element of restriction B.2a give the marginal costs of fixed input use (land and milk quota) per activity. The tenth and eleventh element of restriction B.2a are comparable to the sixth and seventh element, but now reflect the marginal costs and rents from manure policies in the base period. The remaining elements describe the manure policy after 1998 and are therefore not effective in the base period. The effects can be compared to the effects of manure application standards from manure policies in the base period. Again, manure production in the field during grazing is directly at the expense of the manure application room set by manure acceptation and manure policy restrictions. In case this is binding the acceptable nutrients losses and manure application standards will create a rent per dairy cow activity.

The two elements on the right hand side of restriction B.2a give marginal revenue per dairy cow activity.

As discussed the shadow prices of intra-sectorally produced inputs roughage, young animals and animal manure are free variables. This means that they can be positive or negative depending on the market situation. A formal explanation of the existence of free variables can be found in Paris (1991).

The marginal costs per intensive livestock activity given by restriction B.2b can be decomposed into marginal costs of variable input use, excluding costs of intra-sectorally produced inputs (young animals, roughage and manure). Plus the marginal costs of young animals (second element of restriction B.2b), roughage (third element of restriction B.2b) and manure (fourth element of restriction B.2b). Marginal revenue on the right hand side of restriction B.2b gives the shadow price on the product balance times the production of that product per intensive livestock activity. Note that we assume that the intensive livestock as an activity is not directly linked to agricultural land, so shadow costs of land are not included here.

The marginal costs per arable crop, vegetables in the open and flower bulb activity consist of marginal costs of variable input use, excluding costs of intra-sectorally produced inputs and use of nutrients (first element of restriction B.2c). The second element of restriction B.2c gives the marginal costs of the nutrients per arable crop. This is determined by the shadow price of nutrients times the nutrients requirement per arable crop. The third element is the rent from manure acceptation if manure acceptation restrictions are binding. The fourth, fifth and sixth element of restriction B.2c gives the marginal costs per arable crop of land and quotas for sugar beet and starch potatoes respectively. The seventh, eight and ninth element show that a rent is created when available manure application room at arable crops is a binding restriction.

The first element of restriction B.2d gives the marginal costs of variable input use, excluding costs of intra-sectorally produced inputs and nutrients per remaining grassland and fodder maize activity. The second element gives marginal revenue (negative marginal cost) of roughage per remaining grassland and fodder maize activity. Again, this is made up of the shadow price of roughage per kVEM multiplied with roughage production per activity. The third element of B.2d gives the marginal costs of nutrients per activity. The fourth element gives the marginal revenue from manure acceptation if restrictions on manure acceptation become binding. The fifth element gives the marginal costs of fixed input (land) per activity. The sixth, seventh and eight element of B.2d are rents from manure application if manure policies result in limited use of animal manure per activity marginally.

Shadow price of agricultural products

$$\pi^{1}_{yr} \leq \omega_{yr} - \varepsilon_{yr} Q_{yr} \qquad \forall\, y, r \qquad \text{B.3}$$

Restriction B3 says that if demand for y in region r is positive the shadow price π^{1}_{yr} associated with the product balance is less than or equal to the equilibrium price of the product in that region. The equilibrium price is given by the inverse demand function (see Appendix E).

Shadow prices of nutrients

A minimum quantity of nutrients from mineral fertilizer or animal manure is required for all crop and dairy cow activities (see restriction A.5). Restriction B.4 states that the shadow price of nutrients (nitrogen (N) or phosphorus (P)) must be smaller than or equal to the price of nutrients from mineral fertilizer. The shadow price of nutrient f equals the price of that nutrient from mineral fertilizer (a) if mineral fertilizers are used to fulfill nutrient requirement f and (b) if total nutrient application does not exceed minimum requirement. The shadow price of nutrient f is less than the price of that nutrient from mineral fertilizer, when only animal manure is used and total application of workable nutrients does not exceed the minimum requirement. The shadow price of an individual nutrient equals zero when application of workable nutrients exceeds the minimum requirement. Given fixed and maximum yields per crop, the extra nutrients do not contribute to crop growth.

$$\pi^{5}_{ifr} \leq p_{fr} \qquad \forall\, i, f, r \qquad \text{B.4}$$

Under MINAS the shadow price of nutrient f must be smaller than or equal to the price of that nutrient from mineral fertilizer plus the shadow price of the MINAS balance (see restrictions A.12a, A.12b and A.12c). The shadow price of nutrients under MINAS is given by restrictions B.4a, B.4b and B.4c:

$$\pi^{5}_{dfr} \leq p_{fr} + \pi^{12a}_{dfr} \qquad \forall\, d, f, r \qquad \text{B.4a}$$

$$\pi^{5}_{bfr} \leq p_{fr} + \pi^{12b}_{fr} \qquad \forall\, b, f, r \qquad \text{B.4b}$$

$$\pi^{5}_{hfr} \leq p_{fr} + \pi^{12c}_{fr} \qquad \forall\, h, f, r \qquad \text{B.4c}$$

Shadow prices of animal manure

Animal manure produced in animal sheds

$$\pi^{4}_{ar} \geq \sum_{f} \psi_{afr} (\pi^{5}_{dfr} \chi^{a}_{dafr} - (\pi^{6a}_{dfr} + \pi^{11a}_{dfr})) - c_{dar} \qquad \forall\, d, a, r \qquad \text{B.5a}$$

$$\pi^{4}_{ar} \geq \sum_{f} \psi_{afr} (\pi^{5}_{bfr} \chi^{a}_{bafr} - (\pi^{6b}_{fr} + \pi^{11b}_{fr})) - c_{bar} \qquad \forall\, b, a, r \qquad \text{B.5b}$$

$$\pi^{4}_{ar} \geq \sum_{f} \psi_{afr} (\pi^{5}_{hfr} \chi^{a}_{hafr} - (\pi^{6c}_{fr} + \pi^{11c}_{fr})) - c_{har} \qquad \forall\, h, a, r \qquad \text{B.5c}$$

Restrictions B.5a, B.5b and B.5c state that the price of animal manure for activities that use animal manure, is greater than or equal to the sum of the monetary value for workable nutrients minus application costs minus rents on manure application capacity from manure acceptation and manure policy restrictions. From these restrictions it can be concluded that the price of animal manure is not the simple sum of monetary value for workable nutrients, but also depends on rents and application cost. The latter is different for different types of animal manure depending on the dry matter content of animal manure. These conclusions are in line with the analysis of Innes (2000).

After the introduction of MINAS and MAO restrictions B.5a until B.5c will change as follows:

$$\pi_{ar}^{4} \geq \sum_{f} \psi_{afr} (\pi_{dfr}^{5} \chi_{dafr}^{a} - (\pi_{dfr}^{6a} + \pi_{dfr}^{12a} + \pi_{dfr}^{13a})) - c_{dar} \quad \forall\, d,a,r \qquad \text{B.5d}$$

$$\pi_{ar}^{4} \geq \sum_{f} \psi_{afr} (\pi_{bfr}^{5} \chi_{bafr}^{a} - (\pi_{fr}^{6b} + \pi_{fr}^{12b} + \pi_{fr}^{13b})) - c_{bar} \quad \forall\, b,a,r \qquad \text{B.5e}$$

$$\pi_{ar}^{4} \geq \sum_{f} \psi_{afr} (\pi_{hfr}^{5} \chi_{hafr}^{a} - (\pi_{fr}^{6c} + \pi_{fr}^{12c} + \pi_{fr}^{13c})) - c_{har} \quad \forall\, h,a,r \qquad \text{B.5f}$$

Animal manure produced in the field

Restriction B.5g states that the shadow price of animal manure produced in the field by grazing dairy cows must be greater than or equal to minus the sum of the shadow prices of the restrictions on the use of animal manure.

$$\pi_{ar}^{4b} \geq \sum_{f} - \psi_{afr}^{p} (\pi_{dfr}^{6a} + \pi_{dfr}^{11a}) \quad \forall\, d,a,r \qquad \text{B.5g}$$

After the introduction of MINAS and MAO restriction B.5g will be replaced by the following restriction:

$$\pi_{ar}^{4b} \geq \sum_{f} - \psi_{afr}^{p} (\pi_{dfr}^{6a} + \pi_{dfr}^{11a} + \pi_{dfr}^{12a}) \quad \forall\, d,a,r \qquad \text{B.5h}$$

Large scale manure processing

$$\pi_{ar}^{4} \geq - p_{a}^{g} \quad \forall\, a,r \qquad \text{B.6}$$

Restriction B.6 states that the shadow price of animal manure must be greater than or equal to minus the shadow price of large scale manure processing. This means that besides the upper limit, given by monetary value of workable nutrients in the manure minus application costs of animal manure, there is also a lower limit on the shadow price of animal manure given by the processing costs of animal manure.

Exports and imports

Restrictions (B.7a), (B.7b) and (B.7c) guarantee that the shadow price of young animals, roughage and manure must be greater than or equal to the exogenous export price. For manure this is only true if manure export is not restricted. If the manure export restriction is binding, the shadow price of animal manure, element one in restriction B.7c, plus the shadow price of manure export restriction, element two in restriction B.7c, must be greater than or equal to the exogenous export price of manure. Restrictions (B.8a), (B.8b) and (B.8c) guarantee that the shadow price of young animals, roughage and manure must be lower than or equal to the exogenous import price.

π^2_{sr}	$\geq$	p^e_s	$\forall\, s, r$	B.7a
$-\pi^2_{sr}$	$\geq$	$-p^i_s$	$\forall\, s, r$	B.8a
π^3_{ur}	$\geq$	p^e_u	$\forall\, u, r$	B.7b
$-\pi^3_{ur}$	$\geq$	$-p^i_u$	$\forall\, u, r$	B.8b
$\overbrace{\pi^4_{ar}}^{1} + \overbrace{\pi^7_{a}}^{2}$	$\geq$	p^e_a	$\forall\, a, r$	B.7c
$-\pi^4_{ar}$	$\geq$	$-p^i_a$	$\forall\, a, r$	B.8c

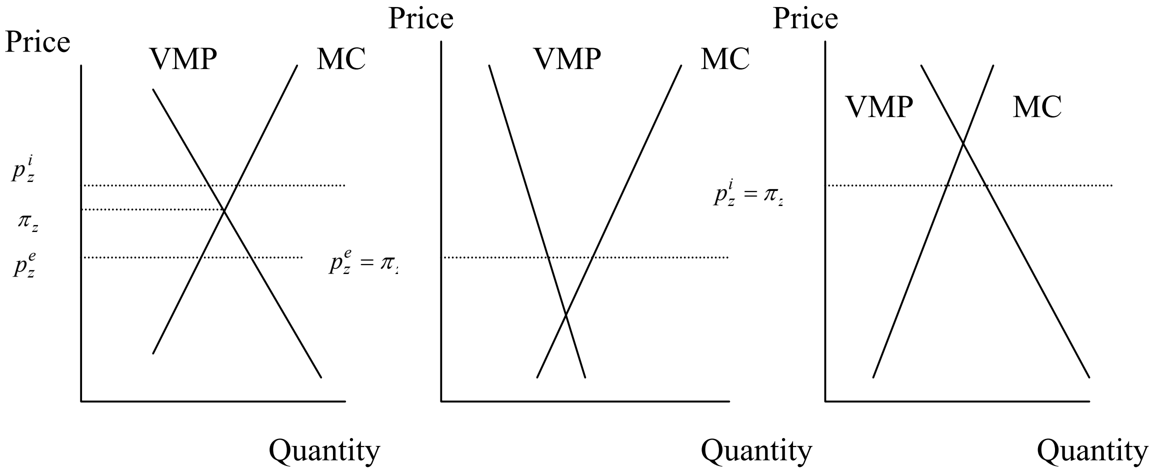

Figure B.2a: Shadow price of intra-sectorally produced input z if it is not traded

Figure B.2b: Shadow price of intra-sectorally produced input z in the case of net exports.

Figure B.2c: Shadow of price intra sectoral-ly produced input z in the case of net imports.

The relationship between the export and import prices of intra-sectorally produced inputs and domestic shadow prices of intra-sectorally produced inputs under free trade is demonstrated in figures B.2a, B.2b and B.2c. In these figures it is assumed that profits are maximized and production levels are given by the intersection between demand (VMP) and inverse supply functions (MC). Figure B.2a shows that the shadow price π_z of an intra-sectorally produced input lies between the export price and the import price if there is no trade with the rest of the world. Figure B.2b shows that under free trade the shadow price equals the export price in the case of a net-export position of the intra-sectorally produced input. The price p_z^e in figure B.2b is greater than the price that would clear the domestic market. All units of the intra-sectorally produced input would be exported unless the domestic consumers are willing to pay the same price. The final outcome is that producers of the intra-sectorally produced input receive the higher export price for all units they produce (Vousden, 1990: 44). Figure B.2c shows that under free trade the shadow price equals the import price p_z^i in the case of a net-import position of the intra-sectorally produced input. The import price is lower than the price that would clear the domestic markets and all units would be imported unless the domestic producers are willing to produce against lower import prices.

The ceteris paribus effect of a binding limit on manure exports to the rest of the world on total profits and distribution of profits to domestic use and production activities of animal manure is graphically demonstrated in figure B.3. Here MC is the inverse supply function of animal manure. Profits are maximized at the intersection point between line MC line and price line $p^{e}_{a.}$. Price $p^{e}_{a.}$ denotes the average national f.o.b. export price of animal manure. Under free trade, the excess of domestic production of animal manure ($S_{a.}$) over domestic consumption ($Q_{a.}$) of animal manure is exported to the rest of the world and all units receive the export price (Vousden, 1990: 44). Now we introduce a restriction (quota) on manure export of ($S^{r}_{a.}$-$Q_{a.}$). In this example we assume that domestic consumption ($Q_{a.}$) is constant. The average domestic manure price decreases to $\pi^{4}_{a.}$. The shadow price of the export quota equals ($\pi^{7}_{a} = p^{e}_{a.} - \pi^{4}_{a.}$) and results from the fact that the export quota decouples the domestic price from the price on the rest of the world. The loss for the agricultural sector as a whole under the quota is given by the area b. This area is the net outcome of a change in producer surplus on domestic production activities of animal manure and a change in producer surplus on domestic use activities of animal manure. The change in producer surplus on production activities of animal manure can be calculated as: -(a+b). The area c equals the rent on manure export. In our case this rent is captured by the domestic production activities of animal manure. The change in the producer surplus on the domestic use activities equals area a. The positive impact of the export quota on producer surplus of domestic use activities occurs because domestic market prices of animal manure decrease.

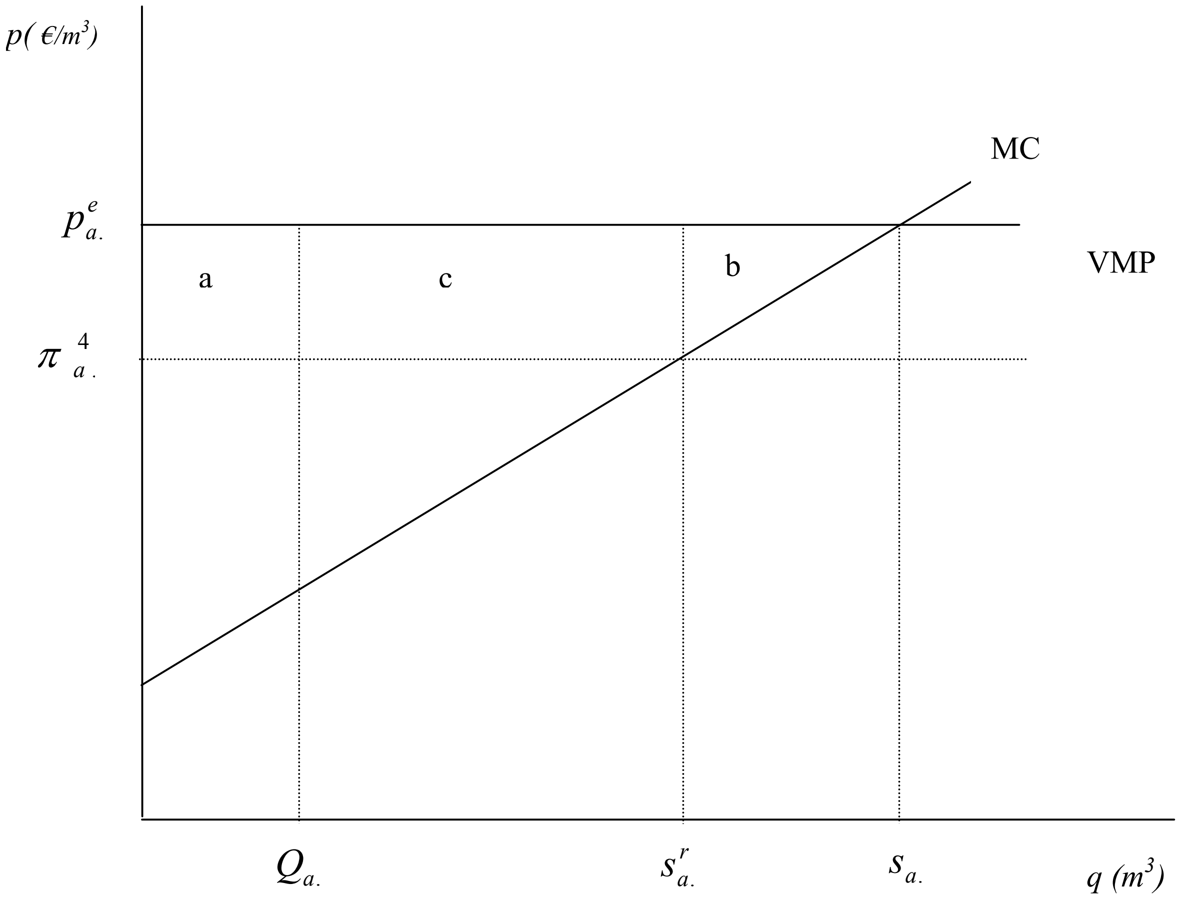

Figure B.3: graphical presentation of upper bound on export of animal manure

Regional transport of young animals and manure

$$\pi_{sr'}^{2} - \pi_{sr}^{2} \quad \leq \quad fc_s \qquad \forall\ s, r, r' \quad \text{B.9a}$$

$$\pi_{ar'}^{4} - \pi_{ar}^{4} \quad \leq \quad d_{rr'} vc_a + fc_a \qquad \forall\ a, r, r' \quad \text{B.9b}$$

Restrictions (B.9a) and (B.9b) arise from the transport problem. Restriction B.9a states that the shadow price of young animals in region of destination minus the shadow price of young animals in region of origin must be less than or equal to transport costs per young animal. Restriction B.9b states that the shadow price of animal manure in region of destination minus the shadow price of manure in region of origin must be less than or equal to the transport costs between both regions.

Shadow price of nutrients surplus from MINAS

Finally, restrictions B.10a and B.10b state that the shadow price of the MINAS restriction per dairy cow activity and per group of remaining grassland and fodder maize activities cannot be higher than the surplus levy.

$$\pi^{12a}_{dfr} \leq p^{p}_{f} \qquad \forall\, d, f, r \qquad \text{B.10a}$$

$$\pi^{12c}_{fr} \leq p^{p}_{f} \qquad \forall\, f, r \qquad \text{B.10b}$$

Graphical presentation of allocation mechanism

If exogenous model variables change, (shadow) prices and quantities adjust until a new equilibrium is reached and the FOC of profit maximization is met again. This adjustment process towards a new equilibrium is graphically demonstrated for three types of products in figures B.4, B.5 and B.6 respectively. Figure B.4 shows the adjustment process of a product that is produced against constant prices; pig meat is used as an example. In figure B.5 the adjustment process is analyzed for a commodity that can be traded internationally, here piglets are used as an example. In figure B.6 the adjustment process is analyzed for a commodity with endogenous prices in DRAM (e.g. consumption potatoes).

Figure B.4, with price (p) at the vertical axis and quantity (Q) on the horizontal axis, shows supply and demand for pig meat. Pig meat is produced by fattening pigs only. Assuming a constant yield per head, the marginal costs function of pig meat can be derived from the marginal costs function of fattening pigs. Marginal costs of fattening pigs (pig meat) increases along the linear marginal costs function (first element in restriction B.2b in Appendix B), but increases step-wise as a relevant restriction becomes binding and the shadow prices of piglets or animal manure increases. The resulting continues but not smoothly upward-sloping marginal costs function or inverse supply function (s^0_j) is given in figure B.4.

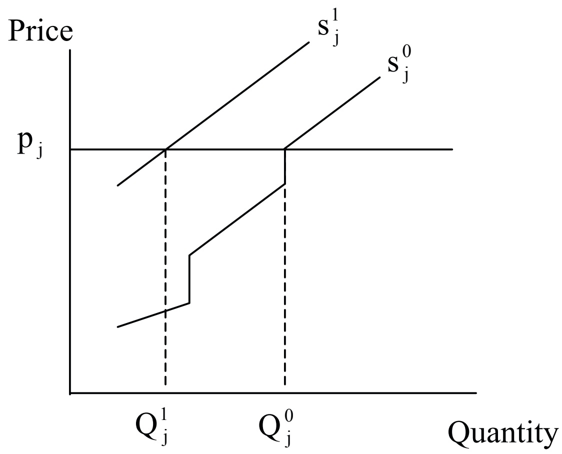

Figure B.4: *Supply and demand of pig meat.*

In the base supply of pig meat equals Q_j^0 and the exogenous price of pig meat equals p_j. After a costs increasing policy switch the inverse supply function shifts to s_j^1 e.g. through a decrease of the price of pig manure (included as a negative costs in restriction B.2b). Marginal costs of production at the same quantity Q_j^0 will increase above marginal revenue given by price p_j in figure B.4. This will result into a decrease of production along the new marginal costs line s_j^1 until marginal costs equals marginal revenue. The new supply of pig meat equals Q_j^1.

Below an example is given for piglets. The inverse supply or marginal costs function in the base is again given by s_j^0. Again, assuming a constant number of piglets per sow, the marginal costs function of piglets can be derived from the marginal costs function of sows. In the base there is export of piglets and the domestic equilibrium price is equal to the export price given by p_j^e the corresponding quantity produced is given by Q_j^0. After introduction of a costs increasing policy the inverse supply function shifts to s_j^1. Production at the same quantity Q_j^0 results into an increase of marginal costs above marginal revenue. In this extreme example the number of sows decreases and the number of piglets decreases along the new inverse supply function

s_j^1 to quantity Q_j^1. In this example the export of piglets totally disappears and the new equilibrium price p_j is found between the export and the import price (p_j^i).

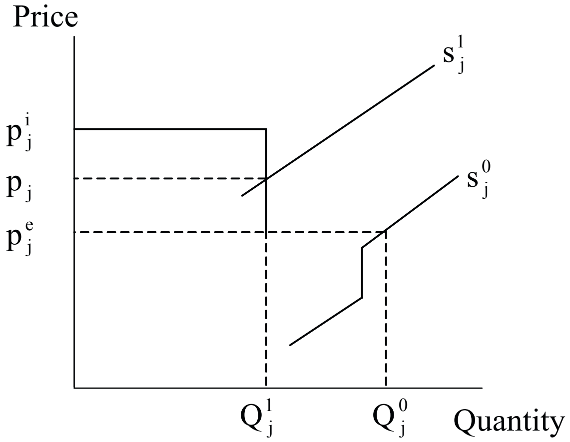

Figure B.5: Supply and demand of piglets in DRAM.

Figure B.6 shows the demand and supply of consumption potatoes. In figure B.6 the down-ward sloping line gives the inverse linear demand function for consumption potatoes. Line s_j^0 is again the marginal costs or inverse supply function in the base. In equilibrium the price of consumption potatoes is given by p_j^0 and the corresponding quantity is given by Q_j^0. After introduction of costs increasing policy, the inverse supply function shifts to s_j^1. At quantity Q_j^0 marginal costs increases above marginal revenue and quantity will reduce along line s_j^1 until marginal costs equals marginal revenue again. In the new equilibrium quantity equals Q_j^1 and the equilibrium price is given by p_j^1.

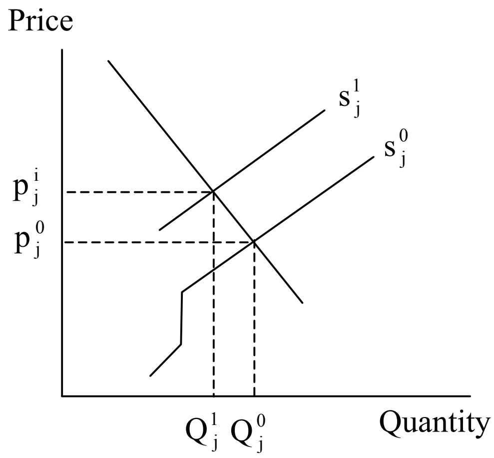

Figure B.6: Supply and demand of consumption potatoes in DRAM.

Appendix C Data

Introduction

The aim of this appendix is to give detailed information about data used to develop a base or benchmark for DRAM describing agricultural production and input use in the base period (1996). The appendix starts with a quantitative description of dairy farming at regional level in the Netherlands. The description concentrates on production and input use per type of dairy cow activity per region. Next, a quantitative description of remaining livestock and crop production in the Netherlands is presented. Main data sources are FADN and the Agricultural Census of Statistics Netherlands (CBS).

Economic and technical variables as prices, yields and input use per unit of production are based on a three-year average from 1993/94-1995/96. A three-year average is used to take into account coincidental variation in yearly results. Resulting profits from agriculture in the base should therefore be seen as normalized profits in the benchmark or base.

Costs and revenues per activity described in this appendix are mostly taken from FADN. The FADN includes yearly about 1500 farms and is a stratified sample of all farms in the Netherlands. The sample contains very detailed information on costs and revenues of individual farms. An important shortcoming of FADN for our purposes is a farm and not activity related approach of bookkeeping. As a result not all variable costs can be allocated to remaining activities. Variable costs per activity presented in this appendix, only include the direct variable costs. These are costs statements that can be directly attributed to individual activities.

Dairy cow activities

Production

Dairy farming in DRAM is represented by nine dairy cow activities per region. The dairy cow activities in DRAM produce milk, meat, young animals, manure, and grass and fodder maize. The inputs are grass, fodder maize, young animals, concentrates, fertilizers and other variable inputs.

Number of dairy cows

The total number of dairy cows per region is taken from the Agricultural Census data of Statistics Netherlands (CBS). Agricultural Census data do not allow to group farms by milk production per dairy cow and nitrogen from mineral fertilizers in kg nitrogen (N) per hectare grassland. For this purpose FADN is used. FADN allows grouping specialized dairy farms by milk production per dairy cow and use of nitrogen from mineral fertilizers (kg N per hectare grassland). Using the number of farms and number of dairy cows per specialized dairy farm per group, the share in total number of dairy cows per region is calculated. Next the shares are used to calculate the number of dairy cows per group from the total number of dairy cows per region given by Agricultural Census data. Specialized dairy farms in FADN are grouped into three regions, sand, clay and peat regions. Only three regions are used because of the limited number of specialized dairy farms per group at the individual regional level. Individual regions in DRAM (14) are linked to the above-mentioned regions (sand, clay and peat), depending on predominant soil type in the DRAM region.

Number of dairy cows per activity at national and regional level is presented in table C1. This table shows that the number of dairy cows per activity with low milk production per dairy cow (LMLN, LMMN, LMHN) is relatively large. Moreover, dairy cows are concentrated in the sand regions. The regional share of a specific dairy cow activity, measured as the number of dairy cows per activity in total number of dairy cows, is presented in figure C.1. From figure C.1 it can be seen that the distribution of dairy cow activities differs per region. For example dairy cow activity LMLN (low milk production per dairy cow and low level of nitrogen from mineral fertilizers per hectare grassland) is relatively important in the peat regions and relatively unimportant in the clay regions.

Table C.1 Total number of dairy cows per dairy cow activity at national and regional level in base (1000 head).

Dairy cow activities	Netherlands	Sand regions	Clay regions	Peat regions
LMLN	305	150	52	103
MMLN	91	57	7	28
HMLN	34	21	8	5
LMMN	298	161	52	85
MMMN	309	144	62	102
HMMN	77	38	16	25
LMHN	219	110	51	58
MMHN	102	65	25	16
HMHN	216	126	46	41
Total[1]	1653	872 (53)	318 (19)	463 (28)

1. Between brackets regional share (in percentages) in the total number of dairy cows.

Source: CBS,LEI, own calculations.

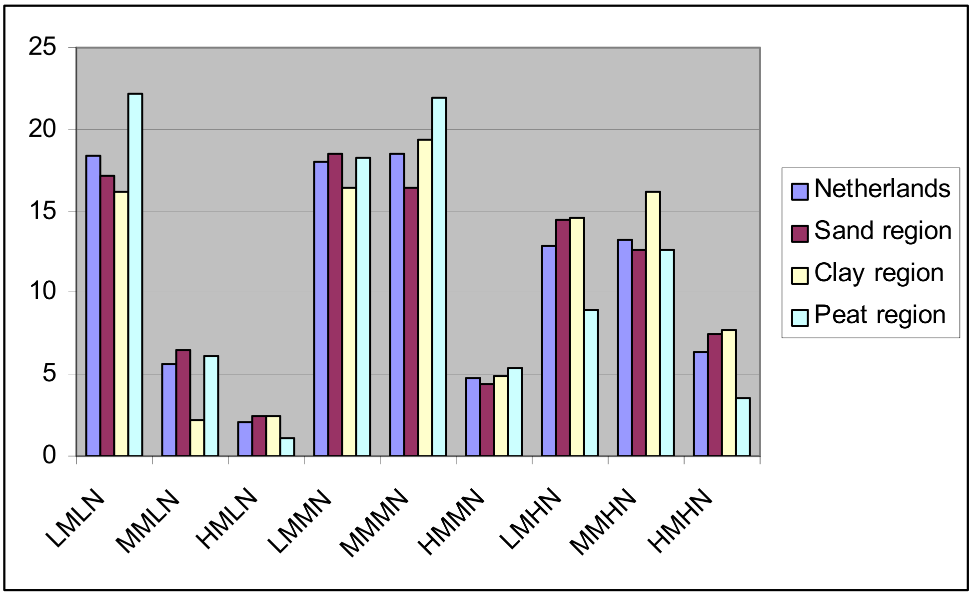

Figure C.1 Regional distribution of dairy cow activities in base (percentages)

Milk

Table C.2 shows average production of milk, beef, grass, fodder maize and manure per dairy cow activity at the national level. Average milk production per dairy cow activity per region is taken from FADN. Notice that milk production per dairy cow activity also differs with the level of nitrogen from mineral fertilizers per hectare grassland. Average milk production per dairy cow ranges from 5.723 kg milk per dairy cow activity LMLN in the clay region to 8.642 kg milk per dairy cow activity HMHN.

Beef

Table C.2 shows that average beef production differs per dairy cow activity. Moreover, there are important differences per region (not shown in table C.2). Beef production per dairy cow is highest in the sand regions and lowest in the peat regions. Among other things this is explained by differences in breed. In the sand regions, more often a half-breed between milk production and beef production is used, whereas other regions use dairy cows, which are more specialized in milk production. The half-breed dairy cows result in higher slaughter weights per dairy and higher beef production per dairy cow at given replacement rates.

Table C.2 Average milk, beef, grass, fodder maize and manure production per dairy cow for different dairy cow activities in base.

Dairy cow activity	Milk production	Beef production	Manure production	Grass	maize
	Ton per dairy cow	Ton per dairy cow	m^3 per dairy cow	kVEM per dairy cow	kVEM per dairy cow
LMLN	5.875	0.136	29.5	4026	669
MMLN	7.430	0.12	31.3	3318	1012
HMLN	8.306	0.111	33.4	2986	1248
LMMN	6.248	0.132	29.6	3134	933
MMMN	7.469	0.123	31.3	3583	755
HMMN	8.389	0.126	33.2	3453	836
LMHN	6.321	0.125	29.7	2943	1044
MMHN	7.461	0.128	31.4	3381	981
HMHN	8.501	0.134	33.4	3181	1183
Netherlands	6.931	0.128	30.7	3415	894

Source: LEI, own calculations.

Calves

DRAM includes different types of calves (calves for own replacement, replacement of beef cattle and replacement of fattening calves) to distribute production of calves from dairy cow activities to other livestock activities. Fixed percentages are used to distribute the calves. Total number of calves produced per dairy cow equals 0.912. It is assumed that calves are used for own replacement (37%), for replacement of beef cattle (13%) and for replacement of fattening calves (50%).

Manure

Manure excretion in volume terms depends on milk production per dairy cow. Table C.2 shows the manure excretion per dairy cow for different dairy cow activities. Data are taken from the Agricultural Census (CBS) combined with information from IKC-V (1993). CBS reports data on manure and nutrients excretion per animal, as a result of a harmonized procedure agreed upon between different statistical and research institutes. CBS gives some regional differentiation, but not a distribution by milk production per dairy cow. In IKC-V (1993) the manure excretion is differentiated by milk production per dairy cow. A fixed correction factor per dairy cow per region (m^3 per cow) is used to equate average regional manure excretion per dairy cow, including calves and heifers, from the Agricultural Census (CBS) with average manure excretion per dairy cow activity from IKC-V data, weighted by the number of dairy cows per activity (CBS, LEI).

Regional manure excretion per dairy cow including calves and heifers ranges from 28.5 m^3 per dairy cow activities LMLN, LMMN and LMHN in the peat region to 33.6 and 33.7 m^3 per dairy cow activities HMLN, HMMN and HMHN in the sand and clay regions respectively.

Grass and fodder maize

Dijk, et al. (1995) estimated a function for feed purchases per hectare on Dutch dairy farms. Farm level data over the period 1985 to 1989 was used taken from FADN. Dijk, et al. (1995) decomposed feed purchases into normative feed requirements of dairy cows and other animals on the farm and a yield function for own grassland production. In their analysis, grassland production, measured in energy content of grass, is a quadratic function of nitrogen (N) input, either from animal manure or mineral fertilizer, measured in mineral fertilizer equivalents. The estimation results from Dijk, et al. (1995) are used to determine own grassland production per dairy cow activity. Results are presented in table C.2. The corresponding workable nitrogen (N) application per hectare grassland is given in table C.5.

Figure C.3 shows the average regional grassland production in kVEM per dairy cow for different dairy cow activities. In general average grassland production per dairy cow is lowest in the sand regions and highest in the peat regions. Besides differences in average workable nitrogen per hectare grassland, this mainly results from differences in the average hectares of grassland per dairy cow.

Fodder maize production is based on an average net production of 10,215 kVEM per hectare. The fodder maize production per dairy cow activity is based on the hectare fodder maize per dairy cow activity from FADN. Figure C.4 shows average regional fodder maize production in kVEM per dairy cow. Because the fodder maize production per hectare is assumed equal for all regions, this figure shows the regional differences in the hectares of fodder maize per dairy cow activity. The highest fodder maize production per dairy cow was found in the sand regions. For the activities with low levels of nitrogen from mineral fertilizers per hectare grassland (LMLN, MMLN and HMLN), there is a positive relationship between milk production per dairy cow and fodder maize production per dairy cow at national level. That is, looking at activities LMLN, MMLN and HMLN only, the fodder maize production per dairy cow per dairy cow activity increases when the milk production per dairy cow per dairy cow activity increases. However, for other activities and at the regional level this relationship can be different.

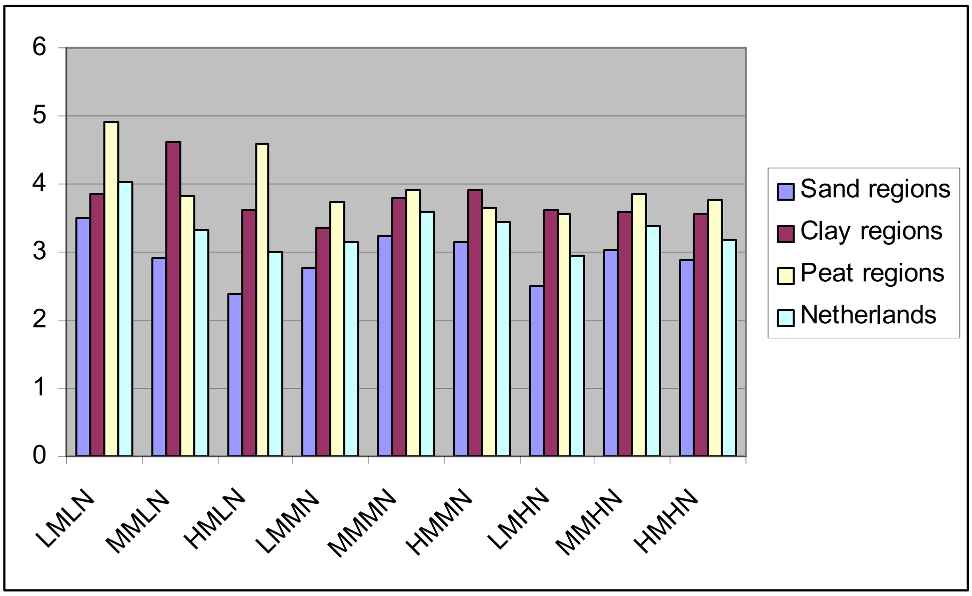

Figure C.3 Regional grassland production in base (kVEM per dairy cow)

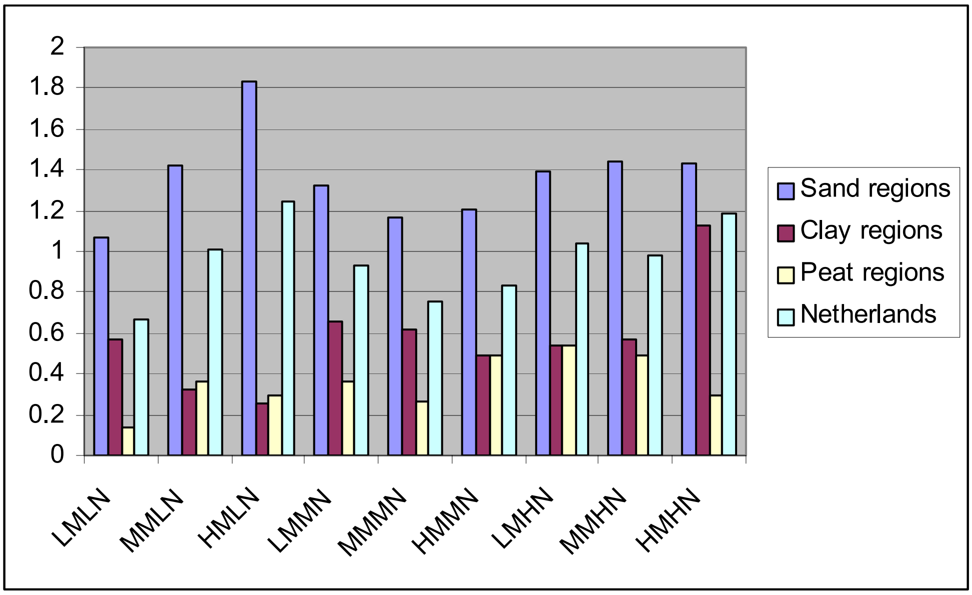

Figure C.4 Regional fodder maize production in base (kVEM per dairy cow)

Output prices

Average prices of outputs produced by dairy cow activities are presented in table C.3. Prices of milk and beef are exogenous. Prices of intra-sectorally produced inputs (young animals, roughage and manure) are endogenous. According to FADN data, the average national milk price in the base equals about € 352 per ton. Regional differences are small.

Table C.3 National average prices of outputs from dairy cow activities in base.

Output	
Milk[1] (€ per ton)	352
Beef[2] (€ per ton)	2,322
Calves for own replacement (€ per head)	189
Calves for replacement of female beef cattle (€ per head)	188
Calves for replacement of fattening calves (€ per head)	143
Grass (€ per 1000 kVEM)	116
Fodder maize (€ per 1000 kVEM)	127
Manure (€ per m^3)	-0.1

1. Received by farmers at average fat percentage; 2. Slaughtered weight.
Source: LEI, Own calculations.

Beef prices are not differentiated per dairy cow activity per region. Table C.3 shows national average prices of intra-sectorally produced inputs (young animals, roughage and manure). These are calculated from regional prices calculated in the base of DRAM. Regional prices equal import prices if intra-sectorally produced inputs are imported from the rest of the world. Regional prices of intra-sectorally produced inputs equal export prices if they are exported to the rest of the world. In case there is no international trade shadow prices lie in between the import and export price (see Appendix B). In case trade is restricted to some upper or lower bound, prices are decoupled from prices in the rest of the world.

The export price of grass equals about € 95 per 1000 kVEM, the export price of fodder maize equals € 118 per 1000 kVEM (IKC-V, 1993). It is assumed that import prices of grass and fodder maize are about 33% higher to take into account transportation costs and quality differences.

Inputs

Feed

To fulfill feed requirements, the dairy cows in DRAM use grass, fodder maize and concentrates. Use of concentrates per dairy cow activity per region, including calves and heifers, is taken directly from FADN. Use of concentrates, grass and fodder maize per calve and heifer, differentiated by regions, is calculated from Werkgroep Uniformering Berekening Mest- en Mineralencijfers (1994a). From the number of calves and heifers per dairy cow, the total use of concentrates of young animals per dairy cow is calculated. Next, use of concentrates per dairy cow can be calculated from total use of concentrates per dairy cow including young animals minus concentrates used by young animals.

Dijk, et al. (1995) present data concerning total feed use per dairy cow, excluding calves and heifers as a function of milk production per dairy cow. Total use of grass and fodder maize per dairy cow activity per region is calculated as the difference between total feed use per dairy cow activity per region given by Dijk, et al. (1995) minus use of concentrates per dairy cow activity per region. Results are presented in Table C.4. To determine the mix of grass and fodder maize it is assumed that use of fodder maize per dairy cow, including calves and heifers, equals the own fodder maize production per dairy cow. However, if the own fodder maize production is less than a minimum quantity given by Werkgroep Uniformering Berekening Mest- en Mineralencijfers (1994a), this minimum quantity is fed to the dairy cows. Grass input per dairy cow equals simply the difference between total use of grass and fodder maize and the use of fodder maize per dairy cow, all measured in kVEM per dairy cow.

Table C.4 Feed use of dairy cows and calves and heifers for replacement in base (kVEM per dairy cow).

	Concen-trates dairy cows	Grass dairy cows	Fodder maize dairy cows	Concentrates calves and heifers	Grass calves and heifers	Fodder maize calves and heifers
LMLN	1737	2161	827	196	1515	70
MMLN	2092	2450	991	208	1575	77
HMLN	2133	2628	1310	215	1548	90
LMMN	1820	2127	954	191	1447	72
MMMN	2056	2661	839	197	1489	68
HMMN	2174	3028	923	212	1592	74
LMHN	1741	2121	1075	200	1468	82
MMHN	2077	2461	1012	208	1542	78
HMHN	2342	2748	1109	231	1654	98
Netherlands	1944	2387	951	202	1512	75

Source: LEI; van Eerdt, 1994a; Dijk, et al., 1995; Own calculations.

Compared to Mandersloot (1992) roughage use of the dairy cows (kVEM per dairy cow) as reported in Table C.4 is quite low. Mandersloot assumes that a dairy cow producing 7,000 kg milk per dairy cow (MMMN) uses almost 4000 kVEM from grass and fodder maize. On the other hand, the consumption of concentrates is much lower (about 1700 kVEM per dairy cow). Werkgroep Uniformering Berekening Mest- en Mineralencijfers (1994a) assumes that the average dairy cow uses about 3300 kVEM per dairy cow from grass and fodder maize and about 1850 kVEM from concentrates. These results are comparable to our results.

Figure C.5 shows regional differences in concentrate use per dairy cow activity. Figure C.5 shows that at the national level there is a positive relationship between concentrate use per dairy cow and milk production per dairy cow. This relationship is especially strong in the peat regions.

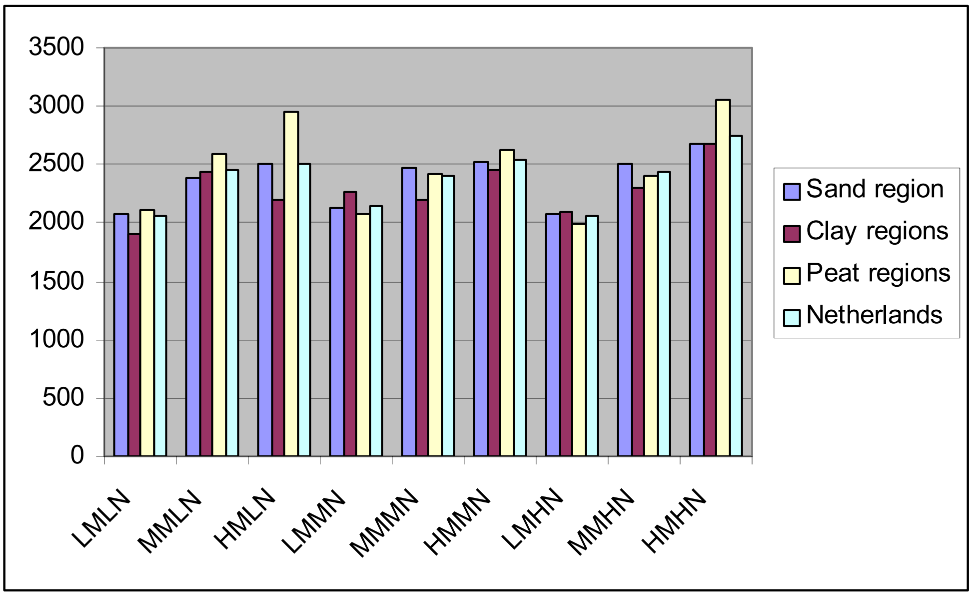

Figure C.5 Concentrate input use per dairy cow activity in base (kg per dairy cow)

Fertilizers

The use of nitrogen (N) and phosphorus (P) per hectare grassland per dairy cow activity is presented in table C.5. Use of workable nitrogen (N) and phosphorus (P) from mineral fertilizers and animal manure depends on the milk quota per hectare (PV, 2001).

Table C.5 Use of nitrogen and phosphorus from animal manure and mineral fertilizers per dairy cow activity in base (kg per hectare grassland).

Dairy cow activity	N from mineral fertilizers	Workable N from animal manure	P from mineral fertilizers	Workable P from animal manure
LMLN	170	47	14.8	15.3
MMLN	208	80	10.5	22.3
HMLN	227	103	7.0	27.1
LMMN	298	77	10.9	21.4
MMMN	307	82	10.0	22.7
HMMN	304	96	7.9	25.8
LMHN	400	89	9.2	24.0
MMHN	407	92	8.7	24.9
HMHN	394	113	5.7	29.3

Source: LEI; Praktijkonderzoek Veehouderij, 2001; Own calculations.

Calves for replacement of dairy cows

The average use of calves for replacement of dairy cows in the base equals 0.34 per dairy cow activity (FADN). Possible differences per dairy cow activity and regional differences are not taken into account.

Other variable inputs

Other cost, include chemicals, seed for grassland and fodder maize, other fertilizers (e.g. potassium) and contract work. Data in value terms per dairy cow activity are taken from FADN. Figure C.6 shows that at national level there is a positive relationship between other input costs and milk production per dairy cow. That is, the other input costs per dairy cow increases as the milk production per dairy cow increases. Furthermore, figure C.6 also shows regional differences in average other input costs per dairy cow activity.

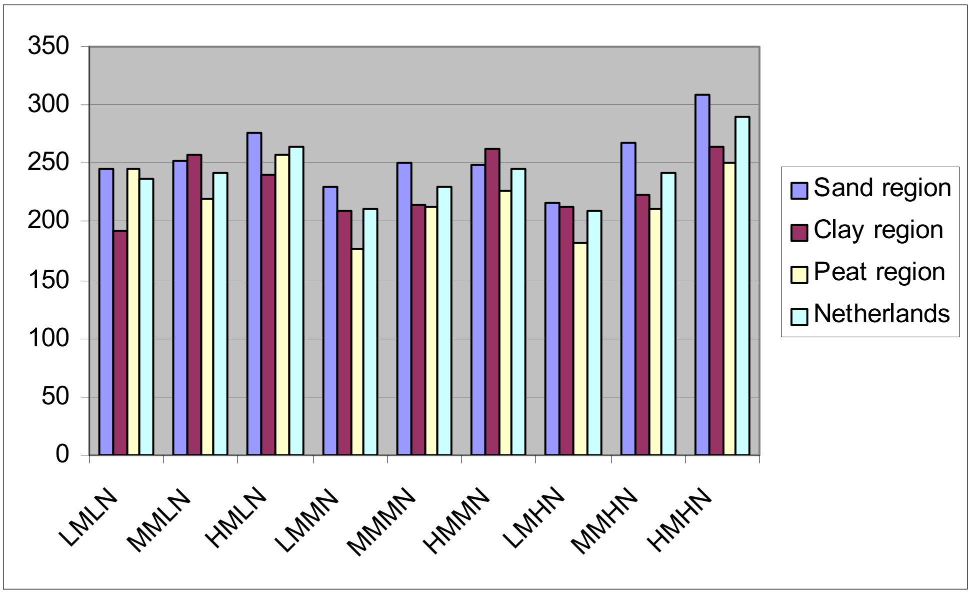

Figure C.6 Other input costs in base (€ per dairy cow)

Source: LEI.

Land

Figure C.7 shows the regional distribution of dairy cows per hectare per dairy cow activity. For dairy cow activities with low nitrogen input per hectare grassland (LMLN, MMLN and HMLN), there is a positive relationship between milk production per dairy cow and number of dairy cows per hectare of grassland and fodder maize at the national level. For other activities and at regional level this relationship can be different.

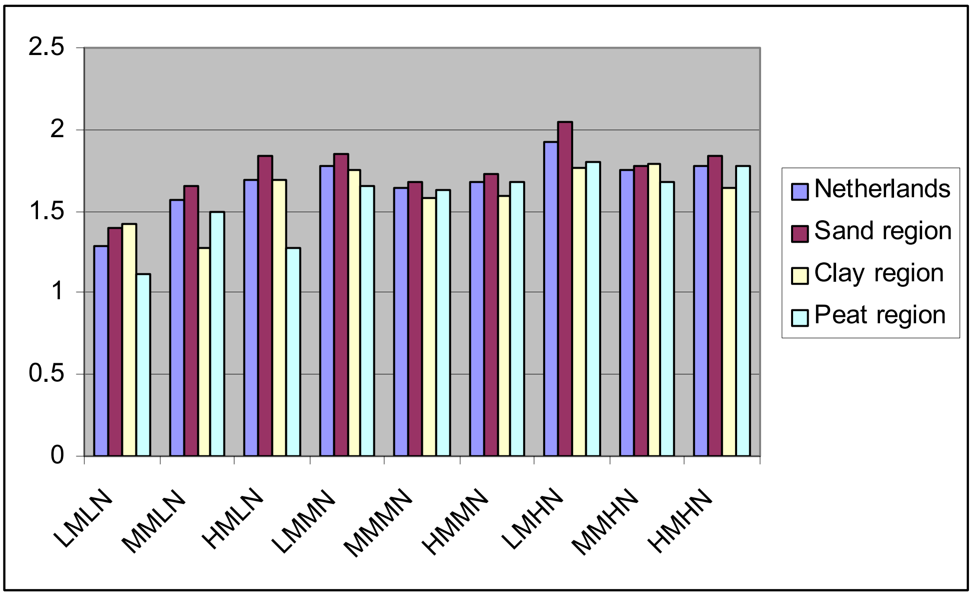

Figure C.7 Number of dairy cows per hectare grassland and fodder maize in base (head per hectare)

Input prices

Average price of concentrates for dairy cows ranges from 171 € per 1000 kg in the sand regions to 166 € per 1000 kg in the clay regions and 163 € per 1000 kg in the peat regions. Average base prices of nitrogen and phosphorus from mineral fertilizers equal 0.46 € per kg N and 0.84 € per kg P. It is assumed that prices are equal in all regions. A price index of 1 is used for the price of other variable inputs.

Profit

Total revenue per dairy cow activity is presented in Table C.6. Sales include milk and beef. Revenue from fertilization is the net result of the revenue from production of animal manure minus costs of fertilization plus rents on manure acceptation. Revenue from production and export of animal manure is the average revenue per dairy cow calculated at regional shadow prices of animal manure and export prices. Revenues from young animals and roughage are also net results of own production and use calculated at shadow prices taken from DRAM.

Average direct payments in the base are calculated as the hectare of fodder maize per dairy cow times the average premium per hectare fodder maize in the period 1993/94-1995/96. Other revenue includes revenue from breeding calves and heifers, service fee dairy cows, lease of milk quotas, sales and growth of horses, sheep and goats, etc.

Table C.6 Sales from marketable outputs (milk and beef), direct payments, revenue from manure, young animals and roughage, total variable costs and profits in base (€ per dairy cow).

	Revenue					Costs	Profit
Dairy cow activity	Sales	Direct payment	Fertilization	Young animals	Roughage	Total variable costs	Profit
LMLN	2,570	16	-46	84	11	865	1,770
MMLN	2,957	24	-59	84	-91	918	1,998
HMLN	3,224	30	-74	84	-153	945	2,167
LMMN	2,561	23	-70	84	-64	817	1,716
MMMN	2,970	18	-83	84	-84	884	2,021
HMMN	3,293	20	-88	84	-153	920	2,236
LMHN	2,559	25	-88	84	-90	795	1,695
MMHN	2,986	24	-99	84	-86	899	2,010
HMHN	3,359	28	-100	84	-139	1,001	2,233
the Netherlands	2,814	22	-76	84	-72	871	1,901

Source: LEI, own calculations.

Net revenue from roughage production and consumption is calculated as sales of roughage (value own grassland and fodder maize production) minus input costs of grassland and fodder maize. This net revenue can be compared to roughage costs per dairy cow activity as reported by FADN. It appears that net roughage costs as calculated by DRAM are lower for dairy cow activities with low milk production per dairy cow and higher for dairy cow activities with high milk production per dairy cow. This might be explained by overestimation of roughage use of high producing dairy cows and underestimation of roughage use of the low producing dairy cows in DRAM.

From table C.6 and C.7 it can be seen that in the base activities with high milk production per cow (HMLN, HMMN, HMHN) have the highest profit per dairy cow and hectare. This is explained by corresponding high milk production per dairy cow and per hectare. At the regional level, profit per hectare of grassland and fodder maize is highest in the sand regions. This is explained by the relative high number of dairy cows per hectare and relative high milk production per hectare in the sand regions.

Table C.7 also shows average profit per dairy cow in € per 100 kg milk. Now the ranking is the opposite: dairy cow activities with a low milk production per cow (LMLN, LMMN, LMHN) have higher profits per 100 kg milk. The relative low level of input use per kilogram milk can explain this. Data analyzes show that at regional level differences in profit per kilogram milk are very small.

Table C.7 Profits in base (revenues minus direct variable cost), € per dairy cow, € per hectare and € per 100 kg milk,

Dairy cow activity	Dairy cow	Ha	Kg milk
LMLN	1,770	2,280	**30.1**
MMLN	1,998	3,111	26.9
HMLN	2,167	3,642	26.1
LMMN	1,716	3,026	27.5
MMMN	2,021	3,310	27.1
HMMN	2,236	3,751	26.7
LMHN	1,695	3,251	26.8
MMHN	2,010	3,499	26.9
HMHN	2,233	**3,956**	26.3

Source: DRAM, own calculations.

Intensive livestock activities

All data related to prices, production and inputs use, necessary to calculate profits (revenue minus direct variable cost) are taken from specialized livestock farms in FADN, if necessary completed with data from other sources. Results from FADN are aggregated to national level. FADN does not allow for disaggregation of intensive livestock data to the regional level. This is due to the limited number of specialized livestock farms included in FADN at the regional level. Hence, differences in profit per intensive livestock activity per region only result from differences in manure prices and to some extent regional differences in prices of young animals.

Production

Numbers and regional concentration

The level of production of the regional livestock activities is presented in Table C.8. From table C.8 and figure C.8 it can be seen that livestock activities concentrate in the

Southern sand region and in the remaining areas. A large concentration of laying hens and fattening calves is found in the Central sand region.

Figure C.9 gives insight into the number of animals per hectare per region relative to the number of animals per hectare in the Netherlands. Again, it is clear that intensive livestock activities are concentrated in the Central sand and Southern sand region.

Table C.8 Number of animals in the Netherlands in base (1000 head).

	Arable areas[1]	Central sand region	Southern sand region	Remaining areas[2]	Netherlands
Beef cattle[3]	54	237	25	134	450
Fattening calves	21	160	294	145	620
Sows	36	435	77	720	1,268
Fattening pigs	220	2,444	637	3,665	6,966
Laying hens	2,014	6,876	5,986	14,098	28,974
Mother animals	321	2,901	603	3,769	7,593

1. Northern clay region, Central clay region, Southern clay region, Peat colonies, Rest of Northern Holland, Rest of Southern Holland.

2. Eastern sand region, Northern sand region, River area, Loess area, Northern peat region, Western peat region.

3. Livestock Units.

Source: CBS.

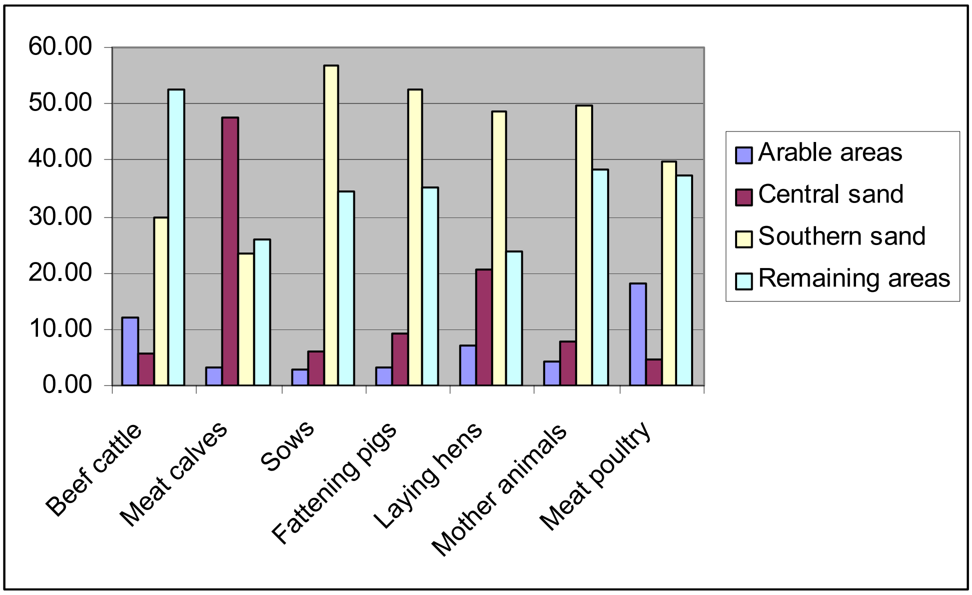

Figure C.8 Regional distribution of livestock activities in base (percentages of total number of intensive livestock activities in the Netherlands).

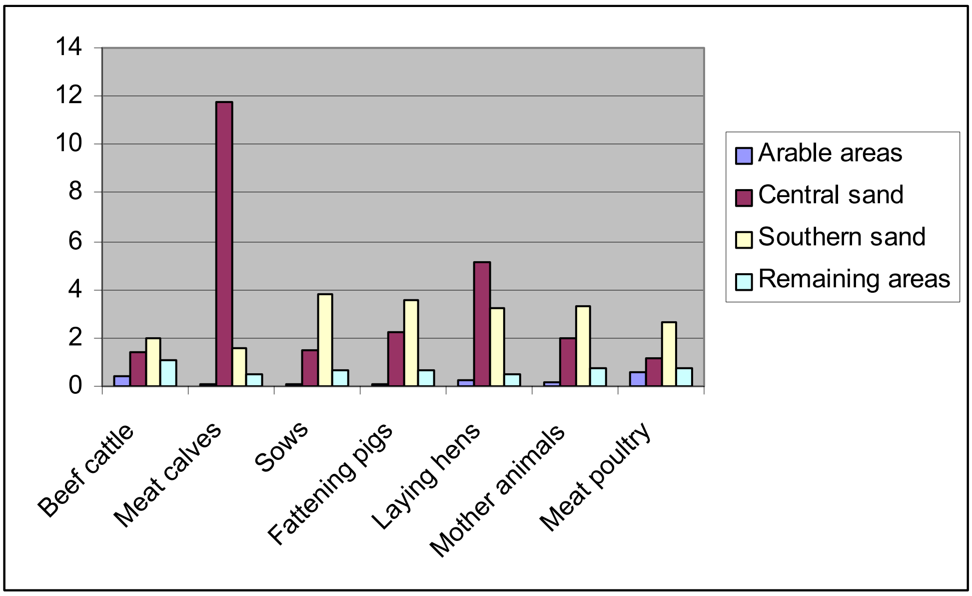

Figure C.9 Relative number of animals per hectare per region in base (average in the Netherlands equals 1)

Meat

Yearly meat production (1000 kg per head) is calculated using the following restriction:

$$d = \frac{a\,b}{c} \qquad \text{(C.3)}$$

Where:

d = meat production per animal (1000 kg per head per year)

a = the price per animal (€ per head)

b = the replacement rate (head per head per year)

c = the meat price (€ per ton).

Prices and replacement rates are calculated at national level (LEI; IKC-V, 1993). This means that possible regional differences are not taken into account. The results of restriction C.3 are presented in table C.9. Table C.9 also shows manure excretion per animal as taken from the Werkgroep Uniformering Berekening Mest- en Mineralencijfers (1993, 1994a, 1994b). Egg production by laying hens and mother animals of meat poultry is based on normative figures (IKC-V, 1993).

Table C.9: Production of livestock activities in base.

Output	Beef cattle	Fattening calves	Sows	Fattening pigs	Laying hens	Mother animals	Meat poultry
Beef/veal (kg per head)	347	451					
Poultry meat/Pig meat (kg per head)			67	242	2	3	16
Eggs (eggs per head)[1]					261	116	
Young animals (head per head)	0.34		21				
Manure (m^3 per head)	12.66	3.84	5.648	1.25	0.072	0.022	0.011

1. Based on 305 and 150 eggs per laying hen and mother animal of meat poultry respectively and replacement in 426 and 469 days respectively (IKC-V, 1993).
Source: LEI, van Eerdt, 1993, 1994a, 1994b, Own calculations.

Output prices

Table C.10 gives average prices of outputs from livestock activities. Price of 'pig meat' from sows fully includes the revenues from young sows between 20 and 50 kg and young sows from more than 50 kg net of own domestic use for replacement of old sows.

Mother animals of meat poultry produce eggs, which are hatched out in a poultry hatchery and sold afterwards as one-day chicken to replace meat poultry. In the base the price of eggs from mother animals equals about € 159 per 1000 eggs whereas the import and export price of one-day chicken to replace meat poultry equal about €259 and € 237 per 1000 one-day chickens respectively. To take into account the extra costs from the hatchery the price of eggs from mother animals of meat poultry equals the price of one-day chicken to replace meat poultry.

If there is trade of young animals between regions, the price in the region of destination equals the price in the region of origin plus transport cost. Regional price differences of piglets (IKC-V, 1993) are explained by transport cost. Given lack of data transport costs of young animals are derived from transport costs of piglets. Transport costs of young animals equal €2.3, €11.3 and €0.0126 per head for piglets, calves and one-day-chicken to replace meat poultry respectively.

Table C.10 Prices of outputs from intensive livestock activities in base.

Output	Beef cattle	Fattening calves	Sows	Fattening pigs	Laying hens	Mother animals	Meat poultry
Beef/veal (€ per ton)	2,735[1]	2,742[2]					
Poultry meat[3]/Pig meat[4] (€ per ton)			3,427	1,368	316	563	727
Eggs[5] (€ per 1000 eggs)					45.3	236.9	
Young animals (€ per head)	190[6]		41				
Manure (€ per m^3)	-1.59	-1.7	-4.7	-5.9	-7.7	-4.0	-1.7

1. Slaughtered weight, second quality; 2. Life weight, first and second quality; 3. Life weight; 4. For pig meat this is the price of slaughtered weight. Revenues from sows include the revenues from young sows. The price of eggs from mother animals of meat poultry equals the price of one-day chicken; 5. Excluding contracts. Prices of eggs from laying hens are based on the price of € 0.71 per kilogram and 0.0636 kilogram per egg; 6. Calves for own replacement, 136 € per head for replacement fattening calves
Source: LEI, Own calculations

Profit

Profits from livestock activities are presented in table C.11. The table shows that in the base the revenue from manure production is negative, but still relatively unimportant. The revenue from manure production (or manure removal cost) for laying hens, mother animals of meat poultry and meat poultry is around zero. This is the outcome of regional transportation from regions with negative prices to regions with positive prices of animal manure.

Table C.11 Sales from marketable outputs, direct payments, revenue from manure, young animals and roughage, total variable costs and profits in base (€ per animal per year).

	Revenue					Costs	Profit
Dairy cow activity	Sales	Direct payment	Manure	Young animals	Roughage	Total variable costs	Profit
Beef cattle[1]	942	42	-20	-235	-189	293	247
Fattening calves	1,237		-7	-279		786	166
Sows	230		-26	790		566	428
Fattening pigs	331		-7	-120		150	53
Laying hens	13		0			11	1
Mother animals of meat poultry	2		0	27		18	11
Meat poultry	12		0	-2		8	1

Source: LEI, own calculations.

Costs of concentrates and other inputs per sow includes the input use of the young sows. Costs of other inputs for mother animals of meat poultry includes the costs of the poultry hatchery. For reason of simplicity it is assumed that the hatchery costs per mother animal per head equals the number of eggs per head times the difference between the price of eggs from mother animals of meat poultry (€ 159 per 1000 eggs) and the price of one-day chicken paid by the producer of meat poultry. In the base the Netherlands is a net-exporter of one-day chicken. Hence the price of one-day chicken equals the export price (€ 237 per 1000 one-day chickens).

Profit per sow is very high because it includes profit for young sows. Profit per mother animal is also rather high because revenues are calculated at prices of one-day chicken.

Crop activities

Production

Activity levels and production

Regional crop activity levels are based on Agricultural Census data from Statistics Netherlands (CBS) aggregated over all farms. Table C.12 shows crop activity levels per region. Other crop activities include the so-called remaining grassland and fodder maize activities. Figure C.10 shows that cropping plans differ per region.

Table C.12 Arable, vegetable in the open and flower bulb activities per region, 1000 hectare.

	Northern clay region	Central clay region	Southern clay region	Peat colonies	Other regions	Netherlands
Cereals	37.9	26.5	58.9	14.7	61.7	199.6
Seed potatoes	12.7	12.5	3.2	0.5	9.7	38.5
Consumption potatoes	3.2	18.6	33.5	0.6	27.4	83.3
Starch potatoes	4.2	0.0	0.0	27.8	29.5	61.6
Sugar beets	12.7	20.8	27.9	12.8	42.1	116.2
Vegetables, flower bulbs	2.9	21.6	22.1	1.2	44.0	91.8
Other[1]	22.3	9.0	41.2	7.7	207.5	287.7
Total	95.7	109.2	186.8	65.2	421.9	878.8

1. Fodder crops, marketable crops, legumes, non-food and remaining grassland and fodder maize activities.

Source: CBS, own calculations.

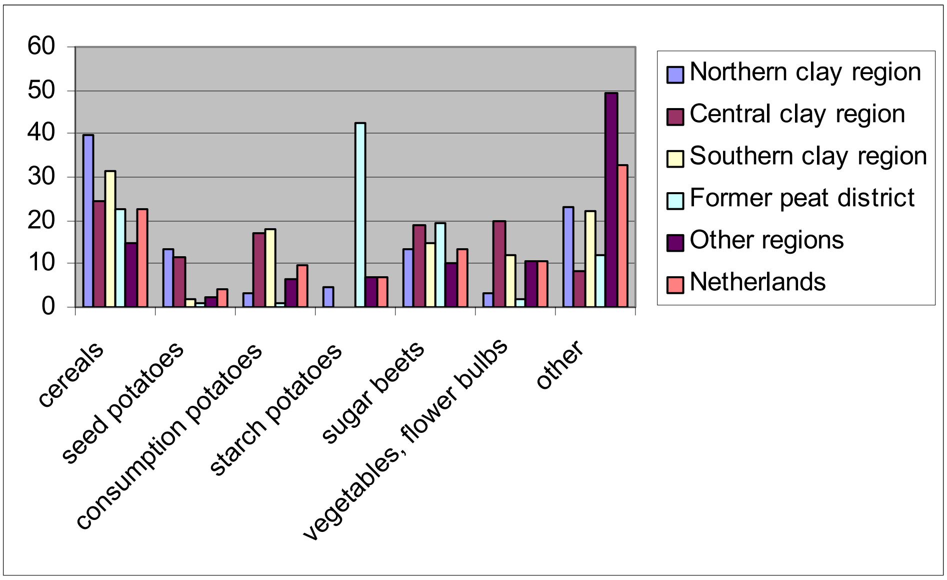

Figure C.10 Share of individual crops in total regional crop area (percentages)

Production per hectare of each crop is calculated for three regions, namely sand, clay and peat regions to take into account differences in dominant soil type per region. Results are presented in table C.13. Again, variables are not calculated for every region in the model because of the sometimes limited number of observations per region. In general revenues from by-products are negligible, except for cereals and marketable crops. At national level the average revenue from by-products of cereals and marketable crops in the base equal €118 per hectare and €161 per hectare respectively.

Table C.13 Yield of crop activities, selected crops, 1000 kg per hectare

	Northern clay region	Central clay region	Southern clay region	Peat colonies	Other regions	Netherlands
Cereals	8.6	8.7	8.8	5.5	6.5	7.8
Consumption-potatoes	47.5	47.5	47.5	46.0	45.8	46.9
Seed potatoes	36.1	35.7	36.1	22.9	29.6	34.2
Starch potatoes	45.1	45.1	45.1	44.2	44.1	44.2
Sugar beets	61.6	61.6	61.6	50.6	53.0	57.3

Source: LEI.

Prices

Regional prices of crops are presented in table C.14. Regional price differences can be large and can be explained by regional differences in quality and composition of the crop, if the crop activity in DRAM is an aggregate of individual crops. Price differences are smaller if prices are managed by EU market regulation schemes (cereals, starch potatoes, sugar beets).

Table C.14 Regional prices of main outputs from arable crop activities, € per ton

	Northern clay region	Central clay region	Southern clay region	Peat colonies	Other regions	Netherlands
Cereals	147	146	146	153	150	147
Consumption-potatoes	116	116	116	83	93	108
Seed potatoes	224	223	223	192	210	220
Starch potatoes	53	53	53	53	53	53
Sugar beets	52	52	52	53	53	52

Source: LEI.

EU direct payments

Direct payments per crop differ between regions, because of differences in yields per hectare and corresponding differences in profit. To take this into account, the Netherlands is divided into a region with high and a region with low production per hectare, with corresponding high and low levels of direct payments. Direct payments per crop per hectare can be calculated from FADN. Results are presented in table C.15.

Table C.15 EU direct payments, € per hectare per crop.

	Northern clay region	Central clay region	Southern clay region	Peat colonies	Other regions	Netherlands
Fodder maize	254	254	254	230	234	236
Cereals	358	358	358	255	279	326
Marketable crops	0	18	23	7	9	17
Legumes	229	333	103	95	233	144
Fodder crops	63	51	94	133	230	216
Fallow land	369	362	367	132	180	264

Source: LEI.

Profits

The inputs distinguished for crop activities are nutrients from mineral fertilizers and animal manure (nitrogen and phosphorus), chemicals and other inputs. Other inputs include services, other fertilizers (including potassium K_2O), seed and planting materials, energy, hired labor and by-products. The main data source is FADN. Normative figures on minimum nutrient requirements are taken from IKC-agv (1994). The use of animal manure and mineral fertilizers per crop are results from DRAM.

Table C.16 Sales from marketable outputs, direct payments, revenue from manure, young animals and roughage, total variable costs and profits in € per hectare.

	Revenue				Costs	Profit
	Sales	Direct payment	Manure	Roughage	Total variable costs	Profit
Cereals	1,269	327	-80		392	1,124
Consumption- potatoes	5,103		-154		1,570	3,379
Seed potatoes	7,544		-113		2,598	4,833
Starch potatoes	2,341		-144		1,019	1,179
Sugar beets	3,008		-92		693	2,223
Fodder crops	1,359	216	21		688	908
Marketable crops	1,683	17	-55		639	1,006
Legumes	1,521	142	-61		634	968
Onion	4,855		-85		1,765	3,005
Vegetable crops, extensively grown	4,077		-22		1,495	2,559
Vegetable crops, intensively grown	9,214		-51		2,196	6,968
Other vegetables	1,621		28		628	1,022
Flower bulbs	33,695		-114		9,669	23,912
Non-food	91	278	-2		45	322
Fodder maize		237	60	1,144	679	761
Grass			-66	702	220	416

Source: LEI, own calculations.

Table C.16 shows that the variation in profits between crops can be large. Crops with high profit per hectare are consumption and seed potatoes, sugar beets, vegetable crops and flower bulbs. In general the revenue from fertilization is negative, which means that in the base the costs of fertilization exceed the rents from acceptation of animal manure.

Appendix D Model calibration: specification of quadratic costs functions with PMP

Introduction

DRAM is calibrated for observed activity levels in the base using PMP (Howitt, 1995a, 1995b and 2002). The PMP approach calibrates the model in three steps. In the first step the quadratic costs functions in restriction A.0 in Appendix A is replaced by linear costs functions. Moreover, activity levels are constrained to observed activity levels. In the second step the parameters of the marginal costs function are derived, such that they are partly based on the shadow prices of the activity constraints. In the third step the linear costs functions are replaced by the quadratic costs functions. This appendix discusses the three steps of the PMP approach.

First step: constrained NLP model

The objective function of the constrained NLP model is written as follows:

$$\begin{aligned}
\max Z = & \overbrace{\sum_y \sum_r (\omega_{yr} - 0.5\varepsilon_{yr} Q_{yr}) Q_{yr}}^{1} - \overbrace{\sum_i \sum_l \sum_r p_{lr} w_{ilr} X_{ir}}^{2} \\
& - \overbrace{\sum_i \sum_f \sum_r p_{fr} F_{ifr}}^{3} + \overbrace{\sum_i \sum_r prem_{ir} X_{ir}}^{4} - \overbrace{\sum_i \sum_a \sum_r c_{iar} A_{iar}}^{5} \\
& + \overbrace{\sum_z \sum_r p^e_{zr} E_{zr}}^{6} - \overbrace{\sum_z \sum_r p^i_{zr} M_{zr}}^{7} - \overbrace{\sum_a \sum_r p^g_a G_{ar}}^{8} \\
& - \overbrace{\sum_z \sum_r \sum_{r'} (d_{rr'} vc_z + fc_z) T_{zrr'}}^{9} - \overbrace{\sum_f \sum_d \sum_r p^p_f P^d_{dfr}}^{10} - \overbrace{\sum_f \sum_r p^p_f P^h_{fr}}^{11}
\end{aligned} \qquad \text{D.1}$$

The index l in restriction D.1 refers to variable inputs, excluding intra-sectorally produced inputs and mineral fertilizers where $l \in S^l$ and $S^l \subset S^j$. The variable p_{lr} is defined as the price of input l in region r (€ per kg; index) The variable w_{ilr} is defined as input l per activity i in region r (kg per ha; kg per head; € per ha; € per head). All other indices and variables are defined in Appendix A.

The objective function of the constrained NLP model D.1 describes variable costs as a linear function of prices and quantities. That is, compared to objective function A.1 in Appendix A, the second element is replaced by a linear variable costs function. The calibration constraint (restriction D.2) puts an upper limit on activity levels based on observed activity levels in the base period (x^*_{ir}) plus a very small number. Regional shadow prices of the calibration constraint, π_{ir} in restriction D.2 give the increase in the objective function if the constraint could be made less restrictive and the level of activities could increase marginally.

$$X_{ir} \leq x^*_{ir} + \varepsilon \qquad \forall i,r \qquad [\pi_{ir}] \qquad \text{D.2}$$

All other restrictions of the constrained NLP model are equal to the model presented in Appendix A.

Second step

In the second step of the PMP procedure, π_{ir} is used to specify a non-linear variable costs function excluding costs of intra-sectorally produced inputs and costs of mineral fertilizers. In DRAM a quadratic variable costs function is used. The general specification of this variable costs function is the following.

$$tvc_{ir} = kk_{ir} + \alpha_{ir} x^*_{ir} + 0.5\beta_{ir}(x^*_{ir})^2 \qquad \forall i,r \qquad \text{D.3}$$

Where:

tvc_{ir} = total variable costs per activity *i* in region *r* (1000 €)

kk_{ir} = constant per activity *i* in region *r* of total variable costs function (1000 €).

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

The first order derivative of the quadratic costs function will result into a linear marginal costs function. Assuming that all cross terms are zero, the linear marginal costs or inverse supply function at the optimal activity level x^*_{ir} is given by:

$$mc_{ir} = \alpha_{ir} + \beta_{ir} x^*_{ir} \qquad \forall i,r \qquad \text{D.4}$$

Where

mc_{ir} = marginal costs of activity *i* in region *r* (€ per head, € per ha) .

The shadow prices of the activity constraints can also be seen as activity specific unobserved costs, including unobserved fixed input costs (capital and labor). At the optimal activity level the marginal costs equals the sum of the observed variable costs (ovc_{ir}) plus the unobserved costs represented by the shadow price (π_{ir}) of the calibration constraint, restriction D.2. The parameters α_{ir} and β_{ir} need to be specified such that

$$mc_{ir} = ovc_{ir} + \pi_{ir} = \alpha_{ir} + \beta_{ir} x^*_{ir} \qquad \forall\, i,r \qquad \text{D.5}$$

Where:

$ovc_{ir} = \sum_l p_{lr} w_{ilr}$ = observed variable costs per activity *i* in region *r* (€ per ha, € per head).

Observed variable costs (ovc_{ir}) include costs of variable input use, excluding costs of intra-sectorally produced inputs and mineral fertilizer. The latter are not included because prices and/or physical input/output coefficients per activity are endogenous variables in DRAM.

Restriction D.5 shows for every activity two parameters to be calculated with only one piece of information. Horner et al. (1992) basically use the following approach to calculate parameters α_{ir} and β_{ir}.[43] The constant is calculated as $\alpha_{ir} = ovc_{ir} - \pi_{ir}$ and the slope parameter is calculated as $\beta_{ir} = \frac{2\pi_{ir}}{x^*_{ir}}$ and it is easily verified that the resulting variable costs function satisfies the restriction given by D.5. The approach followed by Horner et al. (1992) is based on the idea that supply of a preferred activity is more elastic if the shadow price of an activity constraint is small compared

[43] The approach was explained through personal communication by Bob MacGregor from Agriculture Canada. His contribution is greatly appreciated.

to observed variable cost. On the other hand, supply is less elastic if the shadow price of the activity constraint is large compared to observed variable cost. It is argued by Mac Gregor (Agricultural Canada, personal communication) that you expect more action at the margin for marginal crops. On the other hand, it can be expected that preferable crops with small areas and high shadow prices are more stable. The advantage of the approach presented above is that parameters of the marginal costs function are specific per region and activity, while direct estimation is avoided. Direct estimation is very difficult because of limited data sets available at the regional level.

As pointed out by Heckelei (1997) an infinite number of parameter values of the variable costs function will calibrate the model. Moreover, the behavior of the model can be very different, given different values for α_{ir} and β_{ir} (Heckelei, 1997). As there are many possibilities to calibrate the model, the dual values associated with the calibration constraints not only capture 'unobserved' costs or misspecification in technology, but rather any type of model misspecification. Heckelei (1997) mentions the following possible model misspecifications: data errors, aggregation bias, wrong or lacking representation of risk behavior and erroneous price expectations. To address this general problem of PMP, it is suggested to:

- make the specification of the model as rich as possible in order to leave the least amount of 'explanatory' power to the PMP-calibration and minimize it's influence on simulation results;
- to identify and incorporate additional 'hard' prior information into the specification step;
- to generate time series on matrix π to explore and use robust patterns of development over time for simulation.

Paris and Howitt (1998) and Heckelei and Britz (1999) use maximum entropy (ME) to specify the diagonal elements of the matrix β in restriction D.3, D.4 and D.5, but also the off-diagonal elements.[44] By specifying the full matrix, substitution between crops is not only due to resource constraints, but also due to e.g. rotational effects. Paris and Howitt (1998) use only one observation for x^* to estimate the full matrix β . Heckelei

[44] ME is used because the problem is ill-posed, that is the number of restrictions are smaller than the number of variables (negative number of degrees of freedom).

and Britz (1999) use cross-sectional data to increase the number of observations. The resulting matrix β is common across regions and differences in marginal costs depend on differences in crop shares. Their approach is very interesting but due to a lack of time we were not able to include these new elements in the model already.

To solve the problem of degrees of freedom in the standard PMP approach, Horner et al. (1992) suggest using 'hard' prior information about the supply elasticities as well. In this thesis the following procedure is applied. First, supply elasticities are calculated based on given values of the slope of the marginal costs curve (β_{ir}). Second, results are compared with supply elasticities found in the literature. Third, the calculated elasticities are adjusted accordingly or it is assumed that they cannot exceed certain values.

Using restriction D.5, the supply elasticity at the observed activity level can be calculated as:

$$\eta_{ir} = \frac{1}{\beta_{ir}} \frac{(ovc_{ir} + \pi_{ir})}{x_{ir}^{*}} \qquad \forall\, i, r \qquad \text{D.6}$$

Where:

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

We repeat that the slope of the marginal costs curve (β_{ir}) can be calculated as $\beta_{ir} = \frac{2\pi_{ir}}{x_{ir}^{*}}$.

Next, and this also solves the problem of marginal activities with zero values for the shadow prices on the activity constraints, it is assumed that supply elasticities cannot exceed certain values. This addresses the problem of unrealistic high elasticities of supply, due to zero or very low shadow prices on the activity constraint. It is assumed that the supply elasticity for arable crops and remaining grassland and fodder maize activities is equal to or smaller than 2.0. The supply elasticities for all different type of dairy cow activities and for the regional beef cattle activities is put equal to 2.0 in advance. Results are presented tables D.2 and D.3.

Table D.2 shows supply elasticities of intensive livestock activities/products. Supply elasticities of piglets and eggs from laying hens are relatively high in the sand regions. This is mainly explained by the relative high production costs resulting from relative high costs of manure removal.

In general supply elasticities are a function of:

- efficiency changes per activity within individual farms (less drop outs through diseases, relative shift to newer buildings, machineries and equipments);
- efficiency changes per activity over individual farms (ending of less efficient farms and increased share in total production of more efficient farms).

Table D.2 Calculated supply elasticities of intensive livestock products

Livestock activities	Netherlands	Sand regions	Clay regions	Peat regions
Beef cattle	2.0	2.0	2.0	2.0
Veal	3.8	3.8	3.7	3.7
Sows/piglets	1.7	1.7	1.6	1.6
Pig meat	2.3	2.4	2.1	2.1
Eggs/laying hens	2.1	2.1	1.9	1.9
Eggs/mother animals of meat poultry	3.4	3.4	3.2	3.1
Poultry meat	3.1	3.1	3.1	3.1

Source: Own calculations.

Table D.3 presents the calculated supply elasticities of arable crops and remaining grassland and fodder maize. Elasticities of arable crops are relatively high in the sand regions compared to other regions. This corresponds to the relative low profitability of arable crops in the sand regions. Inelastic supply of cereals in the clay regions shows the relative profitability of cereals production in these regions, compared to other regions.

Table D.3 Calculated supply elasticities of crops

Crop activity	Netherlands	Sand regions	Clay regions	Peat regions
Cereals	1.2	1.8	0.9	1.3
Consumption- potatoes	1.1	1.6	1.0	0.9
Seed potatoes	1.3	1.4	1.3	1.1
Fodder crops	1.9	2.0	1.7	1.8
Marketable crops	1.9	2.0	1.9	1.8
Legumes	2.0	2.0	2.0	2.0
Onion	0.8	0.9	0.8	0.9
Vegetable crops, extensively grown	0.7	0.7	0.7	0.6
Vegetable crops, intensively grown	0.6	0.6	0.7	0.6
Other vegetables	0.7	0.8	0.7	0.8
Flower bulbs	0.9	0.8	0.8	1.3
Non-food	1.3	2.0	1.0	1.0
Grass	1.5	1.3	1.9	1.4
Fodder maize	1.9	2.0	1.7	1.7

Source: LEI, Own calculations.

Compared to elasticities used by Jongeneel (2000) and Jensen (1996) (table D.4) it can be concluded that the presented supply elasticities in tables D.2 and D.3 are in some cases rather high. The differences, also found in the literature, are explained by the differences in base period, data and aggregation levels, agricultural structures, policy regions, methodology and definitions. As is mentioned by Jensen (1996) that international comparison of elasticity estimates is very difficult.

Table D.4 Own price elasticities of supply found in the Netherlands and in Denmark[1].

	The Netherlands	Denmark
Beef&veal[2]	0.4-1.25	
Pigs[2]	0.5	0.03+2.58
Poultry[2]	2.0	
Laying hens[2]	5.0	
Cereals	0.18	0.18+0.42
Potatoes	0.023	0.5+3.3
Oilseeds	0.356	0.18+0.48

1. Jongeneel presents short-term intensive management effects for the Netherlands while Jensen presents both extensive and intensive management effects for Denmark. An intensive management effect is the effect on yield per activity. An extensive management effect is the effect on activity level (agricultural structures); 2. Average stock elasticities.

Source: Jongeneel (2000) and Jensen (1996).

Using the supply elasticities defined by restriction D.6, the slope of the marginal costs function (β_{ir}) can be written as:

$$\beta_{ir} = \left(ovc_{ir} + \pi_{ir}\right) / \eta_{ir} x^*_{ir} \qquad \forall\, i, r \qquad \text{D.7}$$

Using restrictions (D.5) and (D.7) the intercept coefficient α_{ir} of the marginal costs function can be written as:

$$\alpha_{ir} = \frac{(ovc_{ir} + \pi_{ir})(\eta_{ir} - 1)}{\eta_{ir}} \qquad \forall\, i, r \qquad \text{D.8}$$

The constant of restriction D.3 can be derived assuming that total variable costs in the calibrated non-linear programming model equals the total observed variable costs in the constrained model. Given this assumption the parameter kk_{ir} can be calculated as:

$$kk_{ir} = (ovc_{ir} - \alpha_{ir} - 0.5\beta_{ir} x^*_{ir}) x^*_{ir} \qquad \forall\, i, r \qquad \text{D.9}$$

Third step

In the third step of PMP the second element of objective function D.1 is replaced by the specified quadratic costs function (D.3). The calibration constraints introduced in step 1 (D.2) are removed.

Appendix E Inverse demand functions

DRAM includes endogenous prices for some marketable outputs. This requires the specification of demand relationships between prices of outputs and quantities. In neo-classical theory, it is assumed that consumers maximize their utility function[45]. Demand relationships are derived from this utility function. This is further explained below.

The objective function of DRAM maximizes the joint surplus of producers and consumers, assuming that markets are perfectly competitive (Takayama and Judge, 1971). The utility function of all consumers (domestic consumers and consumers abroad) is given by restriction (E.1). Note that restriction (E.1) equals the first element in DRAM's objective function presented in Appendix A.

$$\max U = \sum_{y}\sum_{r}(\omega_{yr} - 0.5\varepsilon_{yr}Q_{yr})Q_{yr} \qquad \text{(E.1)}$$

Where Q_{yr} is the quantity of marketable output y in region r and ω_{yr} and ε_{yr} are parameters.

Assuming competitive markets, utility maximizing behavior of consumers and consumer's utility function given by E.1, the first order condition for an optimal solution corresponds to the linear inverse demand function, given by restriction E.2. That is, the consumers maximize their utility when the marginal utility equals the price of that product. See Hazell and Norton (1986) for a geometric and algebraic explanation.

$$P_{yr} = \omega_{yr} - \varepsilon_{yr}Q_{yr} \qquad \text{(E.2)}$$

In restriction E.2 there are two unknown parameters. Additional conditions have to be defined in order to calculate the values of the parameters. An extra restriction is obtained from the price elasticity of total demand (domestic and export) (η_{yr}^{d}), given by:

[45] The budget constraint is not taken into account. It is assumed that the share of consumption of agricultural products in total consumption is very small.

$$\eta_{yr}^{d} = \frac{\partial Q_{yr}}{\partial P_{yr}} \frac{P_{yr}}{Q_{yr}} = -\frac{1}{\varepsilon_{yr}} \frac{P_{yr}}{Q_{yr}} \tag{E.3}$$

Given initial values for consumption, prices and demand elasticities, the parameters of utility function E.1 and the inverse demand functions E.2 can be calculated. The slope parameter is calculated as:

$$\varepsilon_{yr} = -\frac{p_{yr}^{*}}{\eta_{yr}^{d} q_{yr}^{*}} \tag{E.4}$$

Where p_{yr}^{*} and q_{yr}^{*} are initial regional output prices and initial regional output levels respectively. The intercept is simply calculated as:

$$\omega_{yr} = p_{yr}^{*} + \varepsilon_{yr} q_{yr}^{*} \tag{E.5}$$

The demand elasticities used are presented in table E.1. Price elasticities of demand for intra-sectorally produced inputs are determined in the model. Demand for cereals and starch potatoes are assumed perfectly elastic, that is prices are fixed and any quantity can be sold. This is because of the Common Agricultural Policy (CAP) that regulates the markets of these crops.

Table E.1 Price elasticities of demand for arable crops, vegetables in the open and flower bulbs

Consumption potatoes	-0.25
Seed potatoes	-0.60
Marketable crops	-0.81
Onions	-0.17
Vegetable crops, extensively grown	-0.6
Vegetable crops, intensively grown	-0.6
Other vegetables	-0.6
Flower bulbs	-0.7

Sources: Bunte et al. 1998; SPEL-MFSS.

Appendix F Grouping crop activities in DRAM to represent farm types

In DRAM arable crops, vegetables in the open and flower bulbs are sometimes treated as one activity in order to better represent arable, vegetables and flower bulb farms. For vegetable crops and flower bulbs this is realistic because vegetable and flower bulb farms are very specialized with close to 100 percent of their cropping plan consisting of vegetables in the open and flower bulbs (LEI). Table F.1 confirms this. Table F.1 shows that the share of vegetables in the open in total cropping plan on farm type Vegetables in the open in FADN equals 82 percent. Flower bulbs account for 86 percent of the total cropping plan of farm type Flower bulbs in FADN.

Table F.1 Shares of cropping activities in total agricultural land on farm types Vegetables in the open and Flower bulbs in FADN in 1996 (percentages).

	Farm types FADN	
	Vegetables in the open	Flower bulbs
Horticulture in the open	84	89
Of which vegetables in the open	82	0
Of which flower bulbs	0	86
Arable crops	8	4
Grassland	3	4
Other	5	2
Total agricultural land	100	100

Source: LEI.

In table F.2 we compare the national average share of individual arable crops in total area of arable crops in DRAM with the average national cropping plan on arable farms as given by FADN. Table F.2 shows that e.g. the share of seed potatoes in the cropping plan of the average arable farm in FADN exceeds the share of seed potatoes in the average national cropping plan in DRAM. Table F.2 also shows that the share of cereals and consumption potatoes in the average national cropping plan in DRAM exceeds the share on the average arable farm in FADN. This shows that in reality cereals and consumption potatoes are produced by other farm types than specialized arable farms as well, whereas seed potatoes is a more specialized activity at arable farms. Overall the differences are small. Therefore it is concluded that grouping the arable crops in DRAM gives a rather good representation of the cropping plan found at the average Dutch arable farm as reported in FADN.

Table F.1 Total acreages of different arable crops in the Netherlands and shares in national cropping plan according to DRAM and cropping plan of average arable farm in FADN in 1996.

	Level (1000 ha)	DRAM	FADN	
Crop activity		Shares (%)	Shares (%)	Difference (percentage points)
Cereals	199	34	29	5
Consumption- potatoes	83	14	11	3
Seed potatoes	39	7	9	-2
Starch potatoes	62	11	11	0
Sugar beets	116	20	19	1
Fodder crops	7	1	1	0
Marketable crops	26	4	4	0
Legumes	5	1	1	0
Onion	17	3	2	1
Other vegetables	11	2	2	0
Non-food	17	3	0	3
Other arable crops and hired out sowed land	0	0	11	-11
Total arable land	582	100	100	0

Source: LEI, Own calculations.

Appendix G Linking DRAM to the Agricultural Input-Output Table (AIOT)

Introduction

The Agricultural Economics Research Institute in the Netherlands (LEI) constructs on a regular base a so-called Agricultural Input-Output Table (AIOT) as an extension of the national Input-Output table (Koole and van Leeuwen, 2001; van Leeuwen and Verhoog, 1995). The AIOT as developed by LEI is an industry-by-industry table where agricultural industries are made up by homogenous activities. As such it is a combination of an industry-by-industry table and a product-by-product table. Homogenous means that e.g. costs and revenues of dairy cow activities describe the dairy farming industry in the AIOT. Other activities, also found at dairy farms belong to other industries.

DRAM simulates behavior of agricultural producers, but only gives effects at the agricultural sector level. DRAM combined with the AIOT broadens the scope of DRAM to economy wide analyzes. The activity-based approach of DRAM is comparable to the Dutch AIOT approach. This is an advantage with respect to the integration of both systems. Below we first discuss the content of the AIOT that is used for the economy wide analyzes. Second, we discuss the harmonization and integration procedures.

Aggregation of the existing AIOT

We first aggregate industries in the existing Dutch AIOT. Resulting industries, final demand components and primary costs components are presented in figure G.1. The aggregated AIOT includes 29 industries, 2 final demand components: export and consumption and 2 primary costs components: imports and profits (gross value added at producer prices).

In figure G.1 industries are grouped by 'Agricultural industries', 'Horticulture', 'Processing industries', 'Agricultural input delivering' and 'Other industries'. The industries mentioned in column 'Agricultural industries' are also included and described by DRAM. Industries referred to as 'Agricultural input delivering' include all industries with transactions to 'Agricultural industries'. Other industries include all industries without transactions with 'Agricultural industries'. The standard requirements of an input-output table that gross output (row total) equals the sum of intermediate deliveries and primary costs (column total) is met by using profits (at producer prices) as a rest component.

	Industries					**Export**	**Con-sumption**	**Gross output**
Industries	*Agricultural industries*	*Horticulture*	*Processing industries*	*Agricultural input*	*Other industries*			
Agricultural	Cattle farming sector	Horticulture	Dairy industry	*supplies*	Other industries			
industries	Other cattle	glass	Meat industry	Fertiliser industry				
Horticulture	Meat calve sector	Flowers	Vegetables and fruits	Chemical industry				
Processing	Pig sector	Plants	Cereals processing,	Feed industry,				
industries	Laying hens	Mushrooms	human consumption	imported resources				
Agricultural	Meat poultry	Fruit	Cereals processing,	Agricultural services				
input supplies	Arable farming	Trees	animal feed	Other agricultural				
Non-agricultural	Vegetables in the open		Sugar processing	input supplies in-				
industries	Flower bulbs		Flour and meal processing	dustries				
			Gardening					
Imports profits (producer prices)								
Total (producer prices)								
Indirect taxes and subsidies Total (factor costs)								

Figure G.1 Components of the aggregated AIOT

Data harmonization and integration

The AIOT is based on total variable costs per activity also derived from farm level data found in the FADN. Linear programming is applied to distribute the not directly attributable costs from the farm level to the activity level (Verhoog, 1994). Until now we only described direct variable costs per DRAM activity (Appendix C). A harmonization procedure is needed to ensure that both revenues and variable costs per activity are equal in DRAM and in the AIOT. Below the harmonization procedure is further explained.

Assume that subscript *i* refer to outputs and inputs in DRAM, subscript *j* to accounts in the AIOT (not agriculture) and subscript *l* to agricultural industries covered by DRAM's agricultural activities. The ratio (t_{lj}) between the transactions of agricultural industry *l* to account *j* (industries or final demand category: row elements of the AIOT) and the corresponding DRAM transaction is given by:

$$t_{lj} = X_{lj} / \sum_i p_i q_i o_{ilj} \qquad \text{(G.1)}$$

Where X_{lj} is transaction between agricultural industry *l* and account *j* (industries or final demand category: row elements of the AIOT) as observed in the AIOT; p_i is the price of output i, q_i is total supply of output *i* in DRAM and variable o_{ilj} is the linkage variable. The summation sign is needed if more than one output from DRAM belongs to one transaction in the AIOT. However, it is also possible that one output from DRAM belongs to more than one account in the AIOT.

In the same way the ratio (t_{jl}) between deliveries of account *j* (industries or primary costs: column elements of the AIOT) to agricultural industry *l* is given by.[46]

$$t_{jl} = X_{jl} / \sum_i p_i q_i o_{ijl} \qquad \text{(G.2)}$$

Where X_{jl} is the delivery of account *j* (industries or primary costs: column elements of the AIOT) to agricultural industry *l* as observed in the AIOT; p_i is the price of input i, q_i is total use of input *i* in DRAM and variable o_{ijl} is the linkage variable.
Now the transaction between account *j* and agricultural industry *l* is given by:

$$X_{jl} = t_{jl} \sum_i p_i q_i o_{ijl} \qquad \text{(G.3)}$$

The transaction between agricultural industry *l* and account *j* is given by.

$$X_{lj} = t_{lj} \sum_i p_i q_i o_{ilj} \qquad \text{(G.4)}$$

The linkage variable o_{ijl} can be easily calculated if the definition of an output / input in DRAM is identical to a transaction in the AIOT. If this is not the case the distribution of inputs/outputs over agricultural industries *l* and other accounts *j* could follow from make and use tables that give information about the production of outputs and use of inputs per industry. The problem with available make and use tables is that DRAM's product specification is sometimes more disaggregated compared to the product specification in the make and use tables. A more practical approach is chosen, such that values of the linkage variables (o_{ijl} and o_{ilj}) are determined in such a way that the ratios t_{jl} and t_{lj} are as close as possible to 1 (see the examples presented in tables G.1, G.2 and G.3).

[46] Note that the same indices are used for rows and columns.

Examples

Below some examples are given with respect to the linkage of DRAM with the AIOT. The variable o_{ilj} in table G.5 should be interpreted as follows: the value of pig meat from pig farming (an agricultural industry) to the meat industry is assumed equal to 87.5% of the total value of pig meat production in DRAM. This 87.5% is determined exogenous and in the ideal case it should be based on information from existing make and use tables. Variables p_i and q_i are directly taken from the DRAM database and variable X_{lj} is the transaction between accounts *l* and *j* taken from the AIOT. Variable t_{lj} is calculated from restriction G.1. From the first row of table G.1 it can be calculated that 0.996*1.366*1680.3*0.875 = 2000.

Table G.1 Decomposition of transaction between 'Pig farming' and 'Meat industry' in the AIOT.

	t_{lj} (index)	p_i (€/kg)	q_i (1000 tonnes)	o_{ilj} (index)	Total (million €)
Pigmeat	0.996	1.366	1,680.3	0.875	2,000
Meat from old sows	0.996	3.427	84.9	1	290
Transaction (x_{lj})					2,290

Table G.2 Decomposition of transaction between 'Pig farming' and 'Export' in the AIOT.

Output	t_{lj} (index)	p_i (€/kg, €/head)	q_i (1000 tonnes, mln heads)	o_{ilj} (index)	Total (million €)
Pigmeat	1.004	1.366	1,680.3	0.125	288
Meat from old sows	1.004	3.427	84.9	0.65	190
Piglets	1.004	39.41	4.2	1	166
Transaction (x_{lj})					644

Table G.3 Decomposition of transaction between 'Other input deliveries' and 'Pig farming' in the AIOT.

Input	t_{jl} (index)	Activity	p_i (price-index)	q_i (million €)	o_{ilj} (index)	total (million €)
Other inputs	1.05	Fattening pigs	1	63.0	3	199
		Sows	1	145.9	3	459
Transaction (x_{jl})						658

Profits before and after integration with the AIOT are presented in table G.8, G.9 and G.10. To be clear, profits that are consistent with the AIOT are used to calibrate DRAM.

Table G.8 Profits from dairy cow activities before and after integration with the AIOT (€ per dairy cow per year)

Dairy cow activity	Revenue minus direct variable costs	After integration with AIOT
LMLN	1,770	1,197
MMLN	1,998	1,344
HMLN	2,167	1,457
LMMN	1,716	1,145
MMMN	2,021	1,372
HMMN	2,236	1,528
LMHN	1,695	1,125
MMHN	2,010	1,356
HMHN	2,233	1,498
The Netherlands	1,901	1,280

Source: LEI, own calculations.

Table G.9 Profits from intensive livestock activities before and after integration with the AIOT (€ per animal per year)

	Profits	
Activity	Revenue minus direct variable costs	After integration with AIOT
Beef cattle[1]	247	223
Fattening calves	166	114
Sows	428	341
Fattening pigs	53	44
Laying hens	1	4
Mother animals of meat poultry	11	4
Meat poultry	1	2

1. Per livestock unit.

Source: LEI, own calculations.

Table G.10 Profits from arable, vegetables in the open and flower bulb activities before and after integration with the AIOT (€ per hectare per year)

	Profit	
Activity	Revenue minus direct variable costs	After integration with AIOT
Cereals	1,124	778
Consumption- potatoes	3,379	2,542
Seed potatoes	4,833	3,117
Starch potatoes	1,179	730
Sugar beets	2,223	1,676
Fodder crops	908	562
Marketable crops	1,006	614
Legumes	968	488
Onion	3,005	3,249
Vegetable crops, extensively grown	2,559	3,772
Vegetable crops, intensively grown	6,968	9,631
Other vegetables	1,022	1,507
Flower bulbs	23,912	14,392
Non-food	322	289
Fodder maize	761	530
Grass	416	345

Source: LEI, own calculations.

Remarks

Profits are in general lower after integration with the AIOT. As explained this is due to the fact that not directly attributable costs are added to profits.

Essentially the approach presented above means that non-attributable variable costs are spread over the activities as a proportion of the given attributable or direct variable costs per activity. This approach penalizes activities with relative high direct costs per unity (e.g. mother animals of meat poultry, potatoes). The problem could be solved by including 'Other inputs' as an activity specific input, like different type of concentrates are used by different type of animals.
Profit of vegetable crops increases after integration with AIOT. This is mainly due to higher revenue in AIOT than in DRAM at the industry level (about +20%). This is

probably explained by the fact that profit per hectare of vegetable crops in DRAM is based on data from (arable) farms with vegetables in FADN. On these farms, vegetable production is probably less intensive compared to vegetable production on specialized vegetable farms. After integration with AIOT this effect is taken into account.

One further remark on the data is necessary. Given the lack of data the harmonization of DRAM had to be based on the AIOT of 1996. Revenue from laying hens was relatively high in 1996 compared to the average revenue from laying hens in the period 1993/94-1995/96. This explains why profits from laying hens increase sharply after integration with the AIOT of 1996.

Appendix H Price transmission in the input-output model

Introduction

The mixed input-output analyzes (Chapter 5 and chapter 6) are based on volume changes from DRAM, while prices are kept constant to the base year level.

The next step is to take into account effects of price changes. To disentangle the relationships between prices in primary agriculture, prices in other industries, primary costs and final demand components, assumptions concerning price transmissions are necessary.

Below, first the general price index equation will be presented. Second, prices of final demand and primary costs components in output processing and input delivering industries will be discussed. Finally we present gross output and profits in the rest of the economy, taken into account possible price changes.

Price indices

The price index is given by:

$$P_{ij} = \frac{X_{ij}^{v} P_{ij}^{n}}{X_{ij}^{v} P_{ij}^{o}} \tag{H.1}$$

Where index *i* and *j* represent accounts (intermediates, final demand and primary costs components, excluding profits), variable X_{ij}^{v} represents the transaction between account *i* and *j* in volume terms, variable P_{ij}^{n} represents new prices of transactions between *i* and j, P_{ij}^{o} represents prices of transactions between *i* and *j* at base year levels, finally P_{ij} is the price index of transactions between account *i* and account j.

Prices, P_{ij}^{n}, of transactions between primary agriculture and output processing industries and between agricultural input delivering and primary agriculture are known from DRAM. Below it is explained how changes in output and input prices in agriculture are transmitted to the rest of the economy.

Prices of final demand in output processing industries

For the processing industries it is assumed that share of profits in gross output is constant compared to the base. When output prices in primary agriculture are higher, output processing industries have to pay more for their resources. In order to keep the share of profits in gross output constant to the base, it is assumed that processing industries will receive higher prices from final demand components (consumption and exports) and all other prices are assumed constant compared to base[47].

For every industry belonging to output processing the share of profits in gross output is written as:

$$v_2 = \frac{X_{v2}}{X_2^p} = \frac{X_2^p - \sum_j X_{j2}^p}{X_2^p} = \frac{\sum_k X_{2k}^p + \sum_m X_{2m}^p - \sum_j X_{j2}^p}{\sum_k X_{2k}^p + \sum_m X_{2m}^p} \qquad \text{(H.2)}$$

Where the index 2 represents output processing industries (see chapter 5). The indices *k* and *m* refer to industries and final demand components respectively: $2,k,m \in S^i$ and S^j and sets S^i and S^j refer to the accounts *i* and *j* in the AIOT. The index *v* represents profits (*v*=1). Other variables in equation H.2 are explained as follows:

v_2 = Share of profit in gross output in output processing industry 2 (fraction)

X_{v2} = Profits at producer prices in output processing industry 2 (€)

X_2^p = Total gross output in output processing industry 2 (€)

X_{2k}^p = Intermediate sales from output processing industries 2 (€)

X_{2m}^p = Final demand from output processing industry 2 (€)

X_{j2}^p = Intermediate costs plus imports to output processing industry 2 (€)

[47] Essentially this means that there are two prices: one for export and consumption and one for intermediate transactions.

The share of profit in gross output is taken from the initial AIOT table and assumed constant. The new intermediate costs plus imports, X_{j2}^{p}, is a value term and consists of a volume and price component. The price component is affected (as compared to base prices) by price changes of deliveries (resources) from agriculture (resulting from DRAM), while prices of all other transactions to output processing industries are assumed constant. Moreover it is also assumed that prices of intermediate sales from output processing industries to other industries is constant. From these assumptions it follows that price changes of deliveries from primary agriculture to the processing industries (resulting from DRAM) are fully absorbed by price changes of final demand, X_{2m}^{p}, to assure that the share of value added in gross output is constant.

Equation (H.2) can be rewritten as:

$$v_2(\sum_k X_{2k}^p + \sum_m X_{2m}^p) = \sum_k X_{2k}^p + \sum_m X_{2m}^p - \sum_j X_{j2}^p \qquad \text{(H.3a)}$$

$$v_2 \sum_m X_{2m}^p - \sum_m X_{2m}^p = \sum_k X_{2k}^p - v_p \sum_k X_{2k}^p - \sum_j X_{j2}^p \qquad \text{(H.3b)}$$

$$\sum_m X_{2m}^p (v_2 - 1) = \sum_k X_{2k}^p (1 - v_2) - \sum_j X_{j2}^p \qquad \text{(H.3c)}$$

The transaction, X_{2m}^{p}, can be written as $X_{2m}^{p} = X_{2m}^{v} P_{2m}^{o} P_{2m}$ where X_{2m}^{v} represents transactions from agricultural output processing industries to final demand components in volume terms, P_{2m}^{o} represent the transaction prices at base year levels and P_{2m} is the price index. To calculate price index P_{2m} equation (H.3c) can be rewritten as:

$$P_{2m} = (\sum_k X_{2k}^p (1 - v_2) - \sum_j X_{j2}^p)/(M_2(v_2 - 1)) \qquad \text{(H.4)}$$

Where $M_2 = \sum_m X_{2m}^{v} P_{2m}^{0}$

Prices of primary costs in agricultural input delivery industry

When input prices in agriculture increase, agricultural input delivering industries earn more from transactions with agriculture. However, it is assumed that agricultural input delivery industries pay more for their imports as well. Price indices of imports are derived from the assumption that the share of profit in gross output in agricultural input delivery industry is constant and that all prices are constant to the base except the prices of deliveries to agriculture.

The share of profit in gross output is calculated as follows:

$$v_3 = \frac{X_{v3}}{X_3^p} = \frac{X_3^p - \sum_j X_{j3}^p}{X_3^p} = \frac{X_3^p - \sum_k X_{k3}^p - \sum_n X_{n3}^p}{X_3^p} \qquad \text{(H.5)}$$

Where the index 3 represents input delivery industries (see chapter 5). The index *k* and *n* refer to industries and imports respectively: $3,k,n \in S^i$ and S^j and sets S^i and S^j refer to the accounts *i* and *j* in the AIOT. The index *v* represents profits (*v*=1).

Other variables in equation H.5 are explained as follows:

v_3 = Share of value added in gross output in input delivering industry 3 (fraction)

X_{v3} = Profits at producer prices in input delivering industry 3 (€)

X_3^p = Total gross output in input delivering industry 3 (€)

X_{j3}^p = Intermediate costs plus imports in input delivering industry 3 (€)

X_{k3}^p = Intermediate sales to input delivering industry 3 (€)

X_{n3}^p = Imports to input delivering industry 3 (€)

The new gross output from input delivering industries, X_3^p, consists of a volume and price component. The price component is affected (as compared to base prices) by price changes of deliveries to agriculture (resulting from DRAM), while prices of all other sales from input delivering industries are assumed constant.

Again it is also assumed that prices of purchases by input delivering industries from other industries are constant. From these assumptions it follows that price changes of deliveries from input delivering industries to primary agriculture are fully absorbed by price changes of imports to assure that the share of value added in gross output is constant.

After some re-arranging imports in the input delivering industries, X^{p}_{n3}, is decomposed into a price index, P_{n3}, a volume component, X^{v}_{n3}, and a price component, P^{o}_{n3}, representing price of imports at base year levels. The price index of imports to input delivering industries, P_{n3}, can be calculated as follows:

$$P_{n3} = (X^{p}_{3}(1 - v_{3}) - \sum_{k} X^{p}_{k3}) / N_{3} \qquad \text{(H.6)}$$

Where: $N_{3} = \sum_{n} X^{v}_{n3} P^{o}_{n3}$

Gross output

Based on the explanations presented above the gross output of the different industries can be calculated taken into account possible prices changes. Equation H.7 calculates gross output for primary agricultural industries. Gross output is the sum of the transactions from agricultural industries to the *j* accounts (intermediate deliveries and final demand) in value terms.

$$X^{p}_{1} = \sum_{j} X^{v}_{1j} P^{o}_{1j} P_{1j} \qquad \text{(H.7)}$$

Where the index 1 represents primary agricultural industries (see chapter 5), X^{p}_{1} is gross output from agriculture based on new or scenario prices, X^{v}_{1j} is the transaction from agriculture to account *j* in volume terms, P^{o}_{1j} represent prices of transactions between agriculture and other accounts at base year levels, P_{1j} is the price index given by equation H.1.

Equation H.8 shows the calculation of gross output of the agricultural processing industries.

$$X_2^p = \sum_k X_{2k}^v P_{2k}^o + \sum_m X_{2m}^v P_{2m}^o P_{2m} \tag{H.8}$$

Price index P_{2m} is given by equation (H.4).

Gross output from agricultural input delivering industries is calculated as follows:

$$X_3^p = \sum_j X_{3j}^v P_{3j}^o P_{3j} \tag{H.9}$$

Price index P_{3j} is given by equation (H.1).

As there are no transactions to primary agricultural industries from the group of other industries, the price index P_{4j} is equal to one. Where the index 4 refers to the group of other industries. Gross output of the other industries is equal to:

$$X_4^p = \sum_j X_{4j}^v P_{4j}^o \tag{H.10}$$

Profits

Profits in primary agriculture are calculated as gross output minus the sum of intermediate sales plus imports. With base year prices adjusted to scenario prices through the use of price indices, profits in primary agriculture are calculated as:

$$X_{v1} = X_1^p - \sum_j X_{j1}^v P_{j1}^o P_{j1} \tag{H.11}$$

The prices of purchases from primary agricultural industries by agricultural output processing industries might be changed by DRAM. This is translated into price indices. Profits in agricultural processing industries is calculated as:

$$X_{v2} = X_2^p - \sum_j X_{j2}^v P_{j2}^o P_{j2} \tag{H.12}$$

Where P_{j2} is given by equation (H.1).

It is assumed that changes in prices of sales from agricultural input delivering industries to primary agricultural industries, result from changes in import prices. Profits in agricultural input delivering industries are calculated as:

$$X_{v3} = X_3^p - \sum_k X_{k3}^v P_{k3}^o - \sum_n X_{n3}^v P_{n3}^o P_{n3} \qquad \text{(H.13)}$$

Where P_{n3} is given by equation (H.6).

As there are no transactions from primary agricultural industries to the group of other industries, the price index P_{j4} is equal to one. Profits of the group of other industries is equal to:

$$X_{v4} = X_4^{np} - \sum_j X_{j4}^{nv} P_{j4}^o \qquad \text{(H.14)}$$

Discussion

The above presentation describes the price transmission between agricultural input and output prices and prices in the rest of the economy. Price changes in primary agriculture result in price changes of final demand components (agricultural output processing industries) and imports (input delivering industries), while prices of transactions between agricultural output processing, input delivering and other industries (not agriculture) are assumed constant. This is a reasonable assumption if final demand and imports contain a large share of production value and total costs respectively. Another difficulty is that agricultural output processing industries might import their raw materials as well. However, the procedure presented above assumes that these import prices are constant. In the same way prices of transactions from input delivery industries to final demand components are constant as well. The assumption of constant share of profits in gross output and the way it is implemented here, clearly overestimates price changes of final demand components in output processing industries and price changes of imports in input delivering industries.

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Summary

Introduction

In the last ten to fifteen years the external environment (markets, policy, technology) of the agricultural sector in the Netherlands has changed dramatically creating important effects on agricultural production and profit possibilities. Of special importance are the recent and future changes in the Common Agricultural Policy (CAP) of the European Union (EU) as well as national manure and nutrients policy changes. The aim of this thesis is to describe and apply an agricultural sector model in order to analyze and quantify the effects of the above-mentioned policy changes on agricultural production, profits and the environment at the regional and agricultural sector levels in the Netherlands. To understand the links between production and profits at the sector level, the effects on market prices of aggregated changes in supply and demand should be taken into account. Agricultural sector models can be used to quantify these links and they are especially useful when analyzing important changes in the external environment because of their effect on market prices.

The Dutch Regionalized Agricultural Model (DRAM) is a model with a long history. The focus of DRAM is on the modeling of agricultural production, the allocation of a number of fixed inputs over different agricultural products and on the formation of market prices at the regional level. The first chapter of this thesis provides the background of the economic problems analyzed in this thesis: changes in the CAP of the EU and changes in national manure and nutrients policies in the Netherlands. The first chapter also contains a general description of the characteristics of agricultural sector models and a brief summary of DRAM applications in the past. The objectives of this thesis are also presented and discussed. In short, the objectives of this thesis are to describe the current state-of-the-art of DRAM including features such as Positive Mathematical Programming (PMP), endogenous prices of animal manure and possible technology switches in dairy farming. The second objective is to provide a detailed presentation of the data needed for the benchmark (base) of DRAM. The benchmark of DRAM is a description of agricultural production, input use and agricultural prices in the Netherlands in 1996 (the base period). The third objective is to apply the model to changes in the EU's Common Agricultural Policy (CAP) and the fourth objective is

to apply the model to changes in national manure and nutrients policies in the Netherlands.

Chapter two of this thesis contains a general description of DRAM, including a specification of agricultural inputs and outputs, regions, markets and technology. Chapter three discusses the model specification, the methodology of mathematical programming and model calibration. In chapter four the data base and base year results are described. Moreover, manure transport and manure prices in the model's benchmark are compared with observed data. In chapter five the model is applied to analyze the CAP Reform, including Agenda 2000 and CAP Reform 2003 as if they were introduced in the base period (1996). Chapter five also describes the link between DRAM and an input-output model by way of the method of mixed input-output modeling. Mixed input-output modeling enables us to analyze backward and forward effects on the rest of the economy of changes in primary agricultural production. Chapter six analyzes the effects of national manure and nutrients policies in 2004 as if they were introduced in the base period (1996). Analyses in chapter six include exogenous farm management adjustments to bridge the long period between policies in the 1996 base period and those in 2004, and to counteract negative effects on profits at the sector level. In chapter 7 we end the thesis with conclusions and a discussion of the strengths of DRAM and some areas for improvement. Detailed model and data descriptions can be found in the appendices of this thesis.

Methodology

DRAM can be defined as a comparative static, partial equilibrium, mathematical programming, regionalized model of the Dutch agricultural sector with environmental aspects. Recently the state-of-the-art of these types of models has changed rapidly due to the application of Positive Mathematical Programming (PMP) in mathematical programming models (Howitt, 1995a, 1995b and 2002). Mathematical programming models have been criticized because of their normative character, but the PMP approach yields an almost perfectly calibrated model based on a positive or econometric approach of modeling. This thesis describes the calibration of the model to observed levels of agricultural activities (dairy cows, pigs, different kinds of crops, etc.) in a base period. Moreover, an important contribution of this thesis to the scientific literature is the modeling of manure markets at the regional level in agricultural sector models, which is necessary in order to model national manure and nutrients policies.

General description

Agricultural production in DRAM is defined in terms of agricultural activities at the regional level. Arable crop activities include cereals, legumes, sugar beets, consumption potatoes, seed potatoes, starch potatoes, onions, marketable crops, fodder crops, flower bulbs and three types of vegetables in the open. Forage crop activities are grassland and fodder maize. Livestock activities included in the model represent dairy cows, beef cattle, fattening calves, sows, fattening pigs, laying hens, meat poultry and mother animals of meat poultry. Dairy cow activities are further differentiated into nine dairy cow activities using milk production per dairy cow and use of mineral fertilizer per hectare grassland as the criteria. Arable activities produce only one marketable output. Livestock activities produce at least one marketable output and one intra-sectorally produced input. Intra-sectorally produced inputs are roughage (grass and fodder maize), young animals and animal manure. The different types of dairy cows and the so-called remaining grassland and fodder maize activities produce grass and maize. The different types of dairy cow activities produce grass and maize since the complete farm approach is used to characterize dairy cow activities. Agricultural activities are aggregated to the regional level to describe the regional agricultural sector. Fourteen regions are included in DRAM, differentiated by soil type and concentration of agricultural activities.

Intra-sectorally produced inputs can be transported between regions (except for grass and fodder maize) and can be exported and imported to other countries. Regional balances of supply and demand allow for (shadow) prices of intra-sectorally produced inputs to be determined. Export and import prices of intra-sectorally produced inputs are fixed. Some regional prices of final outputs are endogenous in DRAM. Another important feature of DRAM is that the use of minerals from mineral fertilizer or animal manure is determined endogenously at the activity level. Fixed inputs are land and quota for milk, starch potatoes and sugar beets. Mineral balances stemming from different manure and nutrient policies are modeled over activity groups to take into account differences in behavior between farm types. In this respect all arable crop activities have been grouped together to represent arable farms, but dairy cow activities are modeled separately as they represent different types of dairy farms. Grassland and fodder maize activities are grouped together to model the remaining farm types.

Data

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 are IKC-V (1993), Praktijkonderzoek Veehouderij (2001), IKC-agv (1995) and Praktijkonderzoek Plant & Omgeving B.V. (2001) for technical/economic information at the activity level, and Statistics Netherlands for information about manure and nutrients excretions per animal per year.

CAP reform 2000/2008

Chapter 5 analyzes ceteris paribus the environmental and economic effects of what we have called CAP Reform 2000/2008, in combination with the abolition of milk quota and price support. CAP Reform 2000/2008 includes elements of the Agenda 2000 agreement of March 1999 and the CAP Reform 2003 agreements of June 2003. The integration of DRAM with a mixed input-output (IO) model extends the analysis to the Dutch economy as a whole.

Results show that a comprehensive introduction of CAP Reform 2000/2008 has significant effects on production and profits in agriculture. Results are different per sector and region. In particular the decoupling of direct payments negatively affects production in the beef, meat calves and arable industries. Profits from decoupled direct payments per sector are based on the most recent direct payments per activity and activity levels in the base period. Positive effects of decoupling on profitability in dairy farming and arable farming, including vegetables in the open and flower bulbs, are due to more production flexibility. However, the positive effects of decoupling are offset by lower intervention prices (for skimmed milk powder, butter, cereals, starch potatoes). Under CAP Reform 2000/2008 with fully decoupled direct payments, profits in dairy and arable farming, including vegetables in the open and flower bulbs, decrease by 5.2 % and 3.6 % respectively. Decoupling has a positive effect on the share of relative extensive dairy cow activities in total milk production.

Changes in gross output in agriculture are fed into a mixed IO model to calculate economy wide effects of CAP Reform 2000/2008. It was found that due to the decoupling of direct payments in particular, economy wide effects on profits exceed changes in primary agriculture.

Milk quota abolition, when applied to the agricultural sector in the benchmark situation, will increase milk production in the Netherlands by 27%. The increase in milk production is conditioned by the abolition of price support and by Dutch manure policies. Due to the increase in manure and nutrients supply caused by the increased number of dairy cows, manure prices increase and production and profits in other livestock industries decrease.

Abolition of the milk quota system will substantially increase milk production in the Netherlands in the short to medium term. However, profits in dairy farming will decrease by 22%. This is due to, among other things, lower milk prices after abolition of the milk quota system in the EU, when milk prices will be determined by world market prices. Other agricultural industries are affected as well. Dairy manufacturing and agricultural input delivering industries benefit most of the economic gains of milk quota abolition. Abolition of the milk quota system will increase the share in total milk production of relatively intensive dairy farming systems. Moreover, it will increase both the emission of nitrogen as ammonia and the net nitrogen surplus. Environmental effects differ per region: the increase in emission of nitrogen as ammonia and the net nitrogen surplus are largest in regions with the lowest emission levels in the base.

A sensitivity analysis shows that profits in dairy farming decrease by 29% if higher prices of concentrates, due to increased demand, are taken into account as well.

Manure and nutrients policies

In chapter 6 DRAM is applied to analyze the environmental and economic effects of MINAS 2004 standards and MAO at the regional and sector levels. Some farm management adjustments in dairy farming are added exogenously to the scenarios in order to bridge the rather long period between manure and nutrients policies in the base period (1996) and those in 2004.

Results show that MINAS 2004 standards combined with MAO reduces the net nitrogen (N) surplus by more than 50% compared to benchmark values (1996), while profits in agriculture as a whole increase by about +1.1% or € 91 million compared to benchmark values. The manure policy change has a positive effect on the share of relatively extensive dairy cow activities in total milk production.

Effects on profits are very different per sector and region. On the one hand, profits in dairy farming and arable farming at the national level, including vegetables in the open and flower bulbs, increase by 6.1% and 3.0% respectively. However, profits in dairy farming in the sand region decrease by 4%. At the national level profits in the beef cattle and pig and poultry sectors decrease by 22.6%, 8.1% and 5.2% respectively. For the Dutch economy as a whole, the effect is limited to a decrease of € 122 million (1996 prices).

An additional sensitivity analysis is carried out to obtain more insight into the sensitivity of the results with respect to exogenous farm management adjustments in dairy farming. When fewer farm management adjustments are included, profits in dairy farming at the national level decrease by 4.0%. In this case profits in dairy farming in the sand regions decrease by 13%. The effect on profit in the economy as a whole equals € -472 million compared to benchmark values (1996).

Strengths and areas for improvement

The basis of DRAM in economic theory improves the interpretation and communication of the results. An important strength of DRAM is the complete and consistent description of total agricultural production and input use at the regional level. Since aggregate supply and demand are modeled, it is possible to include endogenous prices of agricultural outputs and intra-sectorally produced inputs. The technical detail included in DRAM makes it suitable for interdisciplinary research. Areas for improvement are related to data handling and model updates, the link with farm models and the modeling of investments and processing industries.

Nederlandse samenvatting

Inleiding

De laatste tien tot vijftien jaar is de externe omgeving (markten, beleid, techniek) waarbinnen de Nederlandse landbouwsector moet opereren aanzienlijk veranderd. Dit heeft belangrijke consequenties voor de omvang van de landbouwproductie, de wijze van produceren en de inkomensmogelijkheden in de landbouw. Met name het Gemeenschappelijk LandbouwBeleid (GLB) van de Europese Unie (EU) en het Nederlandse mest en nutriënten beleid is in de loop der jaren sterk veranderd en aangescherpt. Het doel van dit proefschrift is om inzicht te krijgen in de directe en indirecte economische - en milieutechnische effecten van bovengenoemde veranderingen op de Nederlandse landbouwsector.

Het verband tussen productie, prijzen en inkomen op het geaggregeerde niveau van de sector en rekening houdend met de gevolgen van het gevoerde beleid is het onderwerp van landbouwsector modellen. In dit proefschrift wordt gebruik gemaakt van het Dutch Regionalized Agricultural Model (DRAM). DRAM heeft al een lange historie op het LEI in Den Haag. Het model concentreert zich op de landbouwproductie, verdeling van vaste inputs (productiefactoren) over de verschillende outputs (producten) en de modellering van marktprijzen op regionaal niveau en op sectorniveau.

In hoofdstuk één van dit proefschrift wordt eerst nader ingegaan op veranderingen in het GLB van de EU en het Nederlandse mest en nutriënten beleid. Daarnaast wordt ingegaan op de algemene kenmerken van een landbouwsectormodel en wordt in het kort terug gekeken naar de ontwikkeling en toepassingen van DRAM in het verleden. De doelstellingen van het proefschrift komen vervolgens aan bod. De eerste doelstelling is om een beschrijving te geven van DRAM, zoals het model er nu uitziet, dus de huidige state-of-the-art. Dit is noodzakelijk omdat het model in de loop der jaren aanzienlijk is veranderd. Interessante nieuwe elementen zijn de toepassing van nieuwe calibratie-technieken (Positive Mathematical Programming (PMP)), endogene prijzen van dierlijke mest en mogelijke veranderingen in technologie in de melkveehouderij. Omdat de opzet van het model is veranderd, is natuurlijk ook de benodigde data veranderd. De tweede doelstelling van dit proefschrift is dan ook om een gedetailleerde beschrijving te geven van de gebruikte data in DRAM en van de resultaten van de base-run. De base-run is een simulatie van de basisperiode, in dit proefschrift is dat 1996. De uitkomsten van de base-run worden vergeleken met de waargenomen situatie in de basisperiode. Daarbij gaat het met name om de waargenomen landbouwstructuur (aantal dieren en gewassen), regionale transporten van dierlijke mest, mestprijzen en nutriëntenoverschotten op de bodembalans. De derde doelstelling van dit proefschrift is om het model toe te passen op de veranderingen in het GLB van de EU. De vierde doelstelling is om het model toe te passen op veranderingen in het Nederlandse mest en nutriëntenbeleid.

In hoofdstuk twee van dit proefschrift wordt een algemene beschrijving gegeven van DRAM. Dat wil zeggen een specificatie van inputs en outputs, regio's, markten en technieken die worden meegenomen in DRAM.

Hoofdstuk 3 gaat in op de methode van mathematische programmering en model calibratie.

Hoofdstuk 4 geeft een gedetailleerde beschrijving van de gebruikte data en resultaten van de base run. Modeluitkomsten met betrekking tot regionale transporten van dierlijke mest, mestprijzen en milieu-effecten worden vergeleken met waargenomen data in de basisperiode (1996).

Hoofdstuk 5 en 6 gaan in op effecten van respectievelijk veranderingen in het GLB van de EU en veranderingen in het Nederlandse mest- en nutriëntenbeleid volgens berekeningen met DRAM.

In hoofdstuk 7 wordt dit proefschrift afgesloten met conclusies ten aanzien van de doelstellingen zoals geformuleerd in hoofdstuk 1. Verder gaat hoofdstuk 7 in op de sterke punten van DRAM en op enkele verbeterpunten, waarop mogelijke toekomstige modelontwikkeling zich zou moeten richten.

Algemene beschrijving van DRAM

Economisch handelen van ondernemers (gedrag) wordt in DRAM gesimuleerd door optimalisatie van het inkomen (opbrengst minus variabele kosten) uit landbouwactiviteiten, gegeven technische, economische, ruimtelijke en beleidsmatige restricties. Een belangrijke veronderstelling is dat in de basis uitgegaan wordt van een optimale verdeling van de vaste inputs over de verschillende landbouwactiviteiten, zodanig dat marginale opbrengsten en marginale kosten van de activiteiten in het model aan elkaar gelijk zijn. In dat geval is het inkomen in de landbouwsector maximaal. Het model werkt dan als volgt: bij een verandering in één van de exogene variabelen (bijvoorbeeld prijs van varkensvlees), passen endogene prijzen in het model (bijvoorbeeld de mestprijs van vleesvarkens) en de verdeling van vaste inputs over de landbouwactiviteiten en outputs zich zodanig aan, totdat marginale opbrengsten en marginale kosten overal weer aan elkaar gelijk zijn.

Het aantal transacties van en tussen individuele landbouwbedrijven is natuurlijk enorm groot. Om de omvang van het model te beperken worden individuele bedrijven in DRAM geaggregeerd naar zogenaamde regionale bedrijven. In de huidige versie van DRAM worden 14 regio's onderscheiden. De selectie van de regio's is met name gebaseerd op grondsoort, maar houdt ook rekening met concentratie van sectoren in de verschillende regio's, bijvoorbeeld intensieve veehouderij in het Zuidelijk zandgebied.

Verbruik van inputs (inclusief interne leveringen) en de voortbrenging van outputs wordt in DRAM beschreven op het niveau van landbouwactiviteiten. In totaal beschrijft DRAM 13 akkerbouwactiviteiten, twee ruwvoeractiviteiten (gras en snijmais productie), 7 intensieve veehouderijactiviteiten, inclusief vleesvee en vleeskalveren en 9 verschillende melkveehouderijactiviteiten. Intensieve veehouderijactiviteiten betreffen vleesvee, vleeskalveren, vleesvarkens, fokzeugen, leghennen, vleeskuikens en moederdieren van vleeskuikens. Veehouderijactiviteiten produceren meerdere outputs. Zo produceren de fokzeugen, biggen, vlees en mest. Elk diertype produceert een eigen mestsoort, zo wordt rekening gehouden onder andere met verschillen in mineraleninhoud per type mest en verschillen in mestprijzen per type mest.

Technische input en output coëfficiënten zijn gegeven en vast per activiteit, maar kunnen verschillen per regio. DRAM bevat regionale goederenbalansen van jongvee, ruwvoer en mest (de zogenaamde interne leveringen). Aan de aanbodkant van de balans staan eigen regionale productie, importen uit andere regio's en importen uit het buitenland. Aan de vraagkant van de balans staat eigen regionale consumptie, exporten naar andere regio's en exporten naar het buitenland. De balansen voor dierlijke mest (één mestbalans per type mest, één op één relatie tussen type mest en diersoort) bevat daarnaast ook nog verwerking van dierlijke mest.

Prijzen van interne leveringen worden gedeeltelijk binnen DRAM bepaald als schaduwprijzen op bovengenoemde balansen van vraag en aanbod. Schaduwprijzen geven de bijdrage van de interne levering aan het inkomen in de landbouw. Als een interne levering wordt geëxporteerd (geïmporteerd) dan is de schaduwprijs gelijk aan de gegeven exportprijs (importprijs) van de interne levering. In het geval een interne levering (bijvoorbeeld mest) wordt getransporteerd tussen regio's dan zijn regionale prijsverschillen gelijk aan de transportkosten. Export van mest naar het buitenland wordt beperkt door een bovengrens aan de export van mest. Hierdoor kan de binnenlandse prijs afwijken van de exportprijs.

De gewassen hebben een vaste outputcoëfficiënt per hectare gewas. Om die hoeveelheid output te bereiken zijn een bepaalde hoeveelheid nutriënten (stikstof (N) en fosfor (P)) nodig. De benodigde hoeveelheid kan zowel afkomstig zijn uit kunstmest als uit dierlijke mest. In DRAM wordt daarbij rekening gehouden met verschillen in nutriënteninhoud en werkingspercentages van de nutriënten per mesttype. Het werkingspercentage hangt ook af van het tijdstip van aanwending. Dit tijdstip kan verschillen per regio. Daarnaast wordt de acceptatie van dierlijke mest per groep van activiteiten aan een maximum gebonden.

Variabele inputs (exclusief kunstmest) die worden meegenomen in DRAM betreffen krachtvoer, bestrijdingsmiddelen en overige variabele inputs (overig kunstmest, loonwerk, zaaizaad en pootgoed, energie en bijproducten (als een negatieve input)). Marginale kosten van variabele inputs (exclusief kunstmest) per activiteit worden gemodelleerd als een lineaire functie van de productieomvang. De Positive Mathematical Programming (PMP) benadering wordt gebruikt om de parameters van de marginale kosten functie (of inverse aanbodfunctie) te berekenen zodanig dat de waargenomen productieomvang bijna exact wordt gereproduceerd door het optimalisatiemodel (Howitt, 1995 en 2002).

Marginale kosten worden gemodelleerd als een stijgende en lineaire functie van de productieomvang. Er zijn verschillende redenen waarom marginale kosten op het niveau van de landbouwsector afnemen bij een dalende productieomvang:

- daling in verbruik van aangekochte variabele inputs per eenheid activiteit (efficiency) als gevolg van technische verandering binnen bedrijven (minder uitval door ziekte, oude stallen komen eerder leeg, etc.);
- daling in verbruik van aangekochte variabele inputs per eenheid activiteit (efficiency) als gevolg van technische verandering over de bedrijven heen (bedrijven met relatief hoge marginale kosten stoppen met produceren);

Bij een stijging van de productie nemen marginale kosten juist toe.

Vaste inputs in DRAM zijn grond en quota voor melk, suikerbieten en fabrieksaardappelen. Via een regionale grondbalans wordt voorkomen dat meer grond wordt aangewend dan dat er beschikbaar is. In DRAM wordt uitgegaan van nationale quota voor melk en fabrieksaardappelen en regionale quota voor suikerbieten.

Data

De belangrijkste data bronnen voor DRAM zijn het BedrijvenInformatie Net (BIN) van het LEI, de Landbouwtelling van het Centraal Bureau van de Statistiek (CBS) en de Nederlandse Agrarische Input Output Tabel (AIOT), eveneens ontwikkeld door het LEI. Het BIN bevat jaarlijks ongeveer 1500 bedrijven en is een gestratificeerde steekproef van alle landbouwbedrijven in Nederland. De steekproef bevat gedetailleerde informatie op het gebied van kosten en opbrengsten op bedrijfsniveau. Voor het gebruik in DRAM en in de AIOT moeten kosten en opbrengsten op bedrijfsniveau worden vertaald naar activiteitenniveau. Technische en economische coëfficiënten per activiteit worden vermenigvuldigd met het aantal activiteiten per regio uit de Landbouwtelling om de totale landbouwproductie en de totale input verbruik per regio te bepalen. Kosten en opbrengsten van de verschillende activiteiten in DRAM worden afgestemd op de corresponderende transacties in de AIOT. Andere belangrijke databronnen zijn onder andere IKC-V (1993, 2001) en IKC-agv (1995, 2002). Het CBS levert mest en nutriënten excretie per dier per jaar.

GLB hervorming 2000/2008

In hoofdstuk 5 wordt DRAM toegepast om inzicht te krijgen in de milieu- en de economische effecten van wat in dit proefschrift wordt genoemd, de GLB hervorming 2000/2008, gecombineerd met afschaffing van de melkquotering en ondersteuning van de melkprijs. De GLB hervorming 2000/2008 bevat elementen van de Agenda 2000 overeenkomsten van maart 1999 (onder andere daling interventieprijzen voor granen en rundvlees gecompenseerd door hogere directe betalingen) en de GLB hervorming van juni 2003 (ontkoppeling directe betaling, daling interventieprijzen van boter en mager melkpoeder). Ook wordt ingegaan op de ontwikkeling van een mixed input-output model. Door de integratie van DRAM in een input-output tabel en de toepassing van een mixed input-output model kan inzicht worden verkregen in de doorwerking van veranderingen in de landbouwsector op toeleverende en verwerkende industrie en op de rest van de economie.

Berekeningen met DRAM laten zien dat GLB hervorming 2000/2008 belangrijke gevolgen heeft voor productie en inkomen in de Nederlandse landbouwsector. De effecten zijn verschillend per sub-sector en regio. Ontkoppeling heeft met name negatieve gevolgen voor de omvang van de vleesvee en vleeskalverenhouderij en voor de omvang van de productie in de akkerbouw. Opbrengsten van ontkoppelde directe betalingen per sector worden berekend als directe betaling per hectare of dier vermenigvuldigd met het aantal hectare of dieren per sector in de basis. Het positieve effect van de ontkoppeling is de toegenomen vrijheid om te produceren, zonder dat dat ten koste gaat van de directe betaling (die is immers gekoppeld aan het aantal hectare of dieren in een basis en verder ontkoppeld van productie). Echter dit weegt niet op tegen de daling van de interventieprijzen (voor rundvlees, mager melkpoeder, boter, granen en fabrieksaardappelen) onder de GLB hervorming 2000/2008. Met volledig ontkoppelde betalingen daalt het inkomen in de akkerbouw, vollegrondsgroenteteelt en bloembollenteelt en in de melkveehouderij met respectievelijk 3,6% en 5,2% ten opzichte van de basis in 1996. Ontkoppeling heeft een licht positief effect op het aandeel van de extensieve melkveehouderij in de totale melkproductie in Nederland.

Toepassing van het mixed input-output model laat zien dat de economische gevolgen van de ontkoppeling van de directe betalingen voor de rest van de economie veel groter zijn dan voor de landbouwsector. Dit komt met name door de ontkoppeling van de directe betalingen van de productie.

In dit proefschrift wordt afschaffing van de melkquotering gesimuleerd, gegeven de techniek, het beleid, de landbouwstructuur en de landbouwprijzen in 1996. Na afschaffing van de melkquotering stijgt de melkproductie met 27%. Verdere stijging wordt onder andere tegengegaan door afschaffing van de ondersteuning van de melkprijs en het mest en nutriënten beleid in de basisperiode. Als gevolg van de toename van het aantal melkkoeien en de daarmee gepaard gaande toename van de mest en nutriëntenproductie, neemt de druk op de mestmarkt toe. Hierdoor stijgen de producentenprijzen van dierlijke mest en daalt de productie en het inkomen in de vleesveehouderij en in de intensieve veehouderij.

Afschaffing van de melkquotering leidt tot een sterke daling van de melkprijs, omdat deze dan meer wordt bepaald door de wereldmarktprijs van melk. Dit heeft tot gevolg dat het inkomen in de melkveehouderij op sectorniveau afneemt, namelijk met 22%, ondanks de toegenomen melkproductie. Het inkomen in de overige landbouwsectoren verandert eveneens als gevolg van veranderende prijzen van outputs en interne leveringen. Per saldo profiteert vooral de toeleverende industrie en de verwerkende industrie van afschaffing van de melkquotering.

Afschaffing van de melkquotering leidt tot een toename van het aandeel van de relatief intensieve melkveehouderij in de totale melkproductie in Nederland. Daarnaast neemt de melkproductie met name toe in de klei- en zandgebieden in Nederland en in mindere mate in de weidegebieden. Milieu-effecten (emissie van stikstof (N) als ammoniak en stikstofoverschot op de bodembalans) nemen toe na afschaffing van de melkquotering. Deze effecten zijn zeer verschillend per regio: de toename is met name groot in gebieden met relatief lage emissies en een relatief laag stikstofoverschot op de bodembalans in de basis (1996).

Een gevoeligheidsanalyse laat zien dat het inkomen in de melkveehouderij op sectorniveau met 29% afneemt als tevens rekening wordt gehouden met hogere krachtvoerprijzen als gevolg van een toename van het aantal melkkoeien en een toegenomen vraag naar krachtvoer. In dat geval is de toename van de melkproductie op nationaal niveau beperkt tot 20%.

Mest en nutriënten beleid

In hoofdstuk 6 wordt DRAM toegepast om inzicht te krijgen in de milieu- en de economische effecten van een switch van het mestbeleid in 1996 naar MINAS en MAO in 2004. Een aantal managementaanpassingen in de melkveehouderij worden exogeen meegenomen. Deze liggen op het gebied van hogere melkproductie per koe, lagere stikstofaanwending per hectare grasland, hogere graslandopbrengst per hectare, minder beweiding van de melkkoeien en verbeterde werkingspercentages van dierlijke mest. Behalve wat betreft de lagere stikstofaanwending per hectare grasland, worden bovengenoemde aanpassingen niet gedifferentieerd naar type melkkoe of regio.

Berekeningen met DRAM laten zien dat het stikstofoverschot op de bodembalans met meer dan 50 procent daalt vergeleken met het overschot in de basis van DRAM (1996). Tegelijkertijd neemt het inkomen in de landbouwsector ten opzichte van de basis toe met ongeveer 1,1% oftewel € 91 miljoen. Het aandeel van de melkproductie afkomstig van relatief extensieve melkveebedrijven in de totale melkproductie neemt toe. De inkomenseffecten verschillen echter sterk per sub-sector en regio. Op nationaal niveau neemt het inkomen in de melkveehouderij en in de akkerbouw, inclusief vollegrondsgroenteteelt en bloembollenteelt toe met respectievelijk 6,1% en 3,0%. Echter, het inkomen in de melkveehouderij in de zandgebieden daalt met 4%. Op nationaal niveau daalt het inkomen in de vleesveehouderij, varkenshouderij en in de pluimveehouderij met respectievelijk 22,6%, 8,1% en 5,2%. Het inkomen in de Nederlandse economie als totaal daalt met € 122 miljoen (prijzen van 1996).

Het positieve inkomenseffect in de melkveehouderij en in de landbouw als totaal kan worden verklaard door de positieve inkomenseffecten van de managementaanpassingen in de melkveehouderij die exogeen worden meegenomen. Deze overtreffen de negatieve inkomenseffecten van het aangescherpte mest- en nutriëntenbeleid in de melkveehouderij, met name hogere mestafzetkosten. Door middel van een gevoeligheidsanalyse wordt nagegaan wat de effecten voor de landbouwsector zijn als uitgegaan wordt van aanzienlijk minder managementaanpassingen in de melkveehouderij. Het resultaat is dat in dat geval het inkomen in de melkveehouderij op nationaal niveau daalt met 4%. Met name in de zandgebieden daalt het inkomen in de melkveehouderij scherp, namelijk met 13%. Het totale inkomensverlies in de Nederlandse economie neemt toe tot € 472 miljoen (prijzen van 1996)

Sterke punten van DRAM en enkele verbeterpunten

DRAM is afgeleid van en gebaseerd op de standaard neo-klassieke economische theorie. Dit betekent dat modeluitkomsten eenvoudig zijn te interpreteren en te communiceren met de buitenwacht. Het voordeel van DRAM is ook dat het een integrale en consistente beschrijving geeft van de Nederlandse landbouwsector. Doordat de hele landbouwsector wordt meegenomen, wordt ook rekening gehouden met interacties tussen sub-sectoren. Deze interacties zijn het gevolg van veranderingen in marktprijzen van inputs en outputs als gevolg van veranderingen in de geaggregeerde vraag en aanbod. Mathematische programmeringsmodellen zoals DRAM maken gebruik van een groot detail aan technische data. Hierdoor zijn ze zeer geschikt voor interdisciplinair onderzoek. Verbeterpunten liggen met name op het vlak van data bewerking en model actualisatie, de koppeling met bedrijfsmodellen en de modellering van investeringen en verdere verwerking van landbouwproducten in de verwerkende industrie.

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Curriculum Vitae

Johannes Franciscus Martinus Helming werd geboren op 28 maart 1967 in Terborg gemeente Wisch. Van 1979 tot 1985 doorliep hij het Voorbereidend Wetenschappelijk Onderwijs (V.W.O.) op het Isala College in Silvolde. Vervolgens studeerde hij van 1985 tot 1990 agrarische economie aan de Landbouwuniversiteit in Wageningen. Zijn propadeuse haalde hij met lof. Aan het eind van zijn studie liep hij zes maanden stage aan de Universiteit van Minnesota in de VS. Bij zijn afstuderen waren zijn hoofdvakken Algemene Agrarische Economie, Agrarische Bedrijfseconomie en Staathuishoudkunde.

In oktober 1990, één maand voor zijn afstuderen, begon hij als toegevoegd onderzoeker bij de toenmalige vakgroep Algemene Agrarische Economie van de Landbouwuniversiteit in Wageningen. De onderwijstaak had voornamelijk betrekking op internationale handel, terwijl hij zich in het onderzoek bezig hield met schattingen van micro-econometrische modellen. In oktober 1993 begon hij als wetenschappelijk onderzoeker bij het Landbouweconomisch Instituut (LEI). Daar werd hij verantwoordelijk voor de verdere ontwikkeling en toepassing van agrarische sectormodellen. Onderzoeksresultaten van zijn werk op de Landbouwuniversiteit als bij het LEI zijn gepubliceerd in internationale wetenschappelijke tijdschriften en gepresenteerd tijdens diverse internationale wetenschappelijke congressen.

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