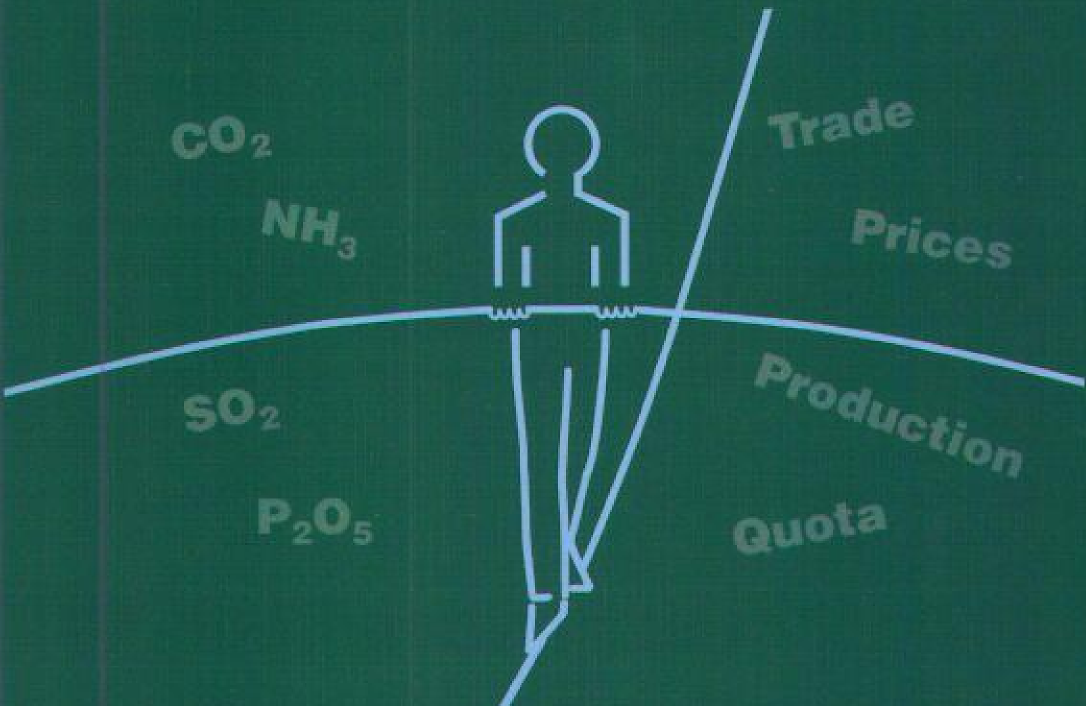
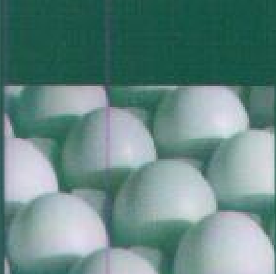
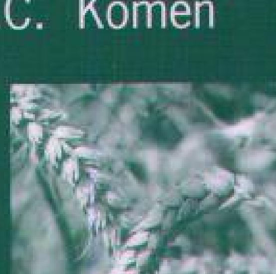


Agriculture and the environment: applied general equilibrium policy analyses for the Netherlands



M.H.C. Komen





Stellingen

1. De inkomenseffecten van een gedwongen inkrimping van de veestapel zijn groter voor de toeleverende en verwerkende industrie dan voor de primaire landbouw omdat laatstgenoemde wordt gecompenseerd door de waarde van de productierechten.
Dit proefschrift.

2. Ten gevolge van bestaande verstorende belastingen kan de introductie van een kleinverbruikersheffing op energie leiden tot een welvaartsverbetering.
Dit proefschrift.

3. Verruiming of afschaffing van melkquota in Nederland leidt tot een geringere productie in de overige dierlijke sectoren ten gevolge van een oplopende schaduwprijs voor fosfaat- en nitraat emissies in de landbouw.
Dit proefschrift.

4. De in 1987 geïntroduceerde mestproductierechten per diersoort en de huidige (voorgenomen) dierrechten impliceren een beperkte verhandelbaarheid van emissierechten en zijn derhalve economisch inefficiënt.

5. Het verdient geen aanbeveling de invoering van een energieheffing te verdedigen met als argument dat de efficiëntie van het belastingsysteem verbetert. Een belastinghervorming, waarbij rekening gehouden wordt met de verstorende werking van bestaande belastingen, is hiervoor een beter middel.

6. Een stelsel van mestafzetcontracten in combinatie met een gebruiksnorm per hectare heeft hetzelfde milieueffect als een stelsel van verhandelbare emissierechten. Echter, in het eerste geval valt de waarde van de eigendomsrechten toe aan de grondeigenaren; in het laatste geval aan de producent van de emissies.

7. Beleidsanalyses met modellen lopen achter de feitelijke ontwikkelingen aan doordat de eerste afgeleide van het beleidsontwikkelingsproces naar de tijd groter is dan de eerste afgeleide van modelontwikkeling naar de tijd.

8. "Models are to be used, not believed".
(H. Theil, In: A. Przeworski (1991). Democracy and the market: Political economic reforms in Eastern Europe and Latin America. Cambridge, Cambridge University Press, p.30).

9. Doordat de aanzet tot een referendum wordt bepaald door een kleine groep direct betrokkenen, moeten vraagtekens gezet worden bij het democratisch gehalte van zo'n stemmingsprocedure.

10. Het progressieve belastingtarief in het huidige Nederlandse belastingstelsel werkt denivellerend omdat de hypotheekrente tegen het marginale tarief wordt afgetrokken.

11. Zij die anderen ervan betichten weinig oog te hebben voor cultuur, passen een te enge en op zichzelf gerichte definitie van cultuur toe.

12. De ervaring leert dat de stelling: "Als het begint te vriezen, dan ontdooien de Friezen", niet alleen opgeld doet voor het daarin genoemde volk.

13. "A classical paper is a paper that everyone refers to, but nobody reads".
(John Roberts, NAKE workshop Groningen, 1997).

14. Net als economische modellen zijn fotomodellen een abstractie van de werkelijkheid.

Stellingen behorende bij het proefschrift:

"Agriculture and the environment: applied general equilibrium policy analyses for the Netherlands"

Wageningen, augustus 2000

Rien Komen

AGRICULTURE AND THE ENVIRONMENT:

APPLIED GENERAL EQUILIBRIUM POLICY ANALYSES

FOR THE NETHERLANDS

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AGRICULTURE AND THE ENVIRONMENT: APPLIED GENERAL EQUILIBRIUM POLICY ANALYSES FOR THE NETHERLANDS

Proefschrift

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Abstract
The purpose of the research described in this thesis is to quantify the economy-wide environmental and economic effects of agricultural and environmental policies and the interaction between these policies in the Netherlands. The basic tool used in this thesis is a static, single-country applied general equilibrium (AGE) model for the Dutch economy, in which environmental relations are incorporated explicitly. Important policy issues dealt with are: (1) the manure policy; (2) the introduction of a small-user energy tax; (3) the reduction of emissions contributing to the environmental indicators eutrophication, the greenhouse effect, acidification and waste accumulation; and (4) the increase of milk quota under a nitrogen emission restriction in agriculture. The simulation results provide insight into the linkages between the economy, agriculture and the environment, the nature of the different environmental problems and the economic consequences of government intervention. The results of the research can be useful for policy makers and interest groups in the Netherlands in designing and evaluating policy.

The Netherlands Organization for Scientific Research and the Foundation for Economic Social-Cultural Geographical and Environmental Sciences (NWO-ESR) is acknowledged for funding this research.

VOORWOORD

Een voorwoord schrijven, na ruim 5 jaar werken aan een proefschrift, is een bijzondere ervaring. Je kunt nog éénmaal terugblikken op hetgeen je al die jaren heeft 'bezig'-gehouden. Was dit in het begin als Onderzoeker In Opleiding (OIO) nog voornamelijk 'consumeren' in de vorm van het volgen van lezingen en het cursusprogramma bij het NAKE, al snel werd het 'produceren' door het schrijven van artikelen, het presenteren van onderzoeksresultaten op congressen in binnen- maar vooral buitenland en, met name het laatste jaar, het vervullen van enkele taken als docent. Vaak was het balanceren op een koord om de juiste weg te kiezen, maar de gedachte dat er uiteindelijk een proefschrift uit zou resulteren zorgde voor het nodige evenwicht. Een aantal mensen dat op welke manier dan ook een bijdrage heeft geleverd aan de totstandkoming van dit proefschrift, noem ik hier.

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Wageningen, augustus 2000 Rien Komen

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CHAPTER 1

GENERAL INTRODUCTION

1.1 Background

There is a growing awareness of actual and potential threats to the natural environment in the form of exhaustion of natural resources, pollution of air, land and water resources, and deterioration in bio-diversity. As in most industrialised countries, concern for maintaining or improving environmental quality has taken a firm place on the policy agenda in the Netherlands. Hence, for policy makers and interest groups, it is important to understand the nature of different environmental problems, the linkages between the economy and the environment, and the economic and environmental consequences of government intervention.

The Dutch economy, agriculture and environment are highly interrelated. Agriculture, industries directly related to agriculture (agribusiness) and international trade in agricultural and food products form a substantial part of Dutch economic activity. Moreover, agricultural production causes a number of specific environmental problems, primarily related to the use of industrial inputs like fertiliser and pesticides. In addition, agriculture also contributes to some general environmental problems like the greenhouse effect, acidification and eutrophication.

In the Netherlands, European Union (EU) price and income support are declining in importance, while EU agri-environmental policies (Potter, 1998) and national environmental policies are coming to the fore. The freezing of support prices since 1984/85 and a substantial reduction in intervention prices in the Common Agricultural Policy (CAP) reform of 1992 facilitated the agreement that concluded the Uruguay Round in 1993. Continuing market imbalances, the EU enlargement and budgetary constraints and the ongoing negotiations under the World Trade Organisation (WTO) create a need for further reform of the CAP, which has led to the Agenda 2000 reform in 1999 (Tracy, 1997; Agra Europe, 1999). Moreover, awareness of environmental problems due to farming practices has led to the integration of environmental considerations into the CAP (Brouwer and van Berkum, 1996), with agri-environmental policies and agricultural support subject to environmental conditions

(NRLO, 1998)[1]. Finally, Dutch agriculture faces an increasing number of national environmental regulations related to a variety of environmental issues (e.g., pesticides, minerals, acidification, greenhouse effect, nature and landscape conservation, etc.). Hence, the importance of environmental policy in Dutch agriculture is increasing relative to other policies.

The Netherlands is a small open economy. Since trade plays an important balancing role between production and consumption, it influences the environment mainly in an indirect way, because the environmental effects of economic activity depend largely on resource use, production technology and consumption (Anderson, 1992a and 1992b; Anderson and Blackhurst, 1992; Whalley, 1991). At the same time, environmental regulation can influence comparative advantage of (agricultural) production and thereby influence the costs and location of production (Siebert, 1974; Cropper and Oates, 1992). The Uruguay Round Agreement in 1993 and the ongoing CAP reform, have put issues of trade and the environment high on the policy agenda. Hence, there is a growing need for information on and analysis of these issues (NRLO, 1994; Perroni and Wigle, 1994).

Three relevant categories of policies can be distinguished that stress the changing policy environment of agriculture and the linkages between the economy, the environment and agriculture: (1) environmental policies that are specific for agriculture; (2) general environmental policies that affect agriculture; and (3) agricultural policies that entail environmental effects. Moreover, given the interrelationships, interactions between these policies can also be expected. Manure policy is an example of an environmental policy specific to agriculture. General environmental policies that will influence agriculture are policies to reduce emissions that cause the greenhouse effect (e.g., an energy tax) and policies to reduce emissions that cause acidification. Examples of agricultural policies that might affect the environment are the CAP and its Agenda 2000 reform. For policy makers and interest groups it is important to know how these policies should be modified to harmonise their sets of objectives with respect to production, income formation, prices, trade, emissions and welfare. Hence, there is a need for empirical research to better understand the interface of agricultural and environmental policies and to consider prospects for policy co-ordination (Just and Antle, 1990; Just and Bockstael, 1991; Johnson et al., 1990).

1 The Agenda 2000 reform of the CAP provides the possibility to link direct payments to environmental criteria (cross compliance). The specific conditions are to be set by member states, so that varying national circumstances can be taken into account (European Commission, 1999).

1.2 Objective and methodology

The objective of this thesis is to determine the economy-wide environmental and economic effects of agricultural and environmental policies and the interactions between these policies, in the Netherlands. Some of the most important policy issues are dealt with in this thesis. Policy simulations are: (1) the manure policy; (2) the small-user energy tax; (3) the reduction of emissions contributing to the environmental indicators eutrophication, the greenhouse effect, acidification and waste accumulation; and (4) the increase of milk quota under a nitrogen emission restriction. The manure policy implies a restriction of intensive livestock farming in the Netherlands, which is intended to reduce the environmental problems linked to the excess supply of minerals. The energy tax simulation follows the introduction of the small-user energy tax in the Netherlands in 1996, which has potential effects on energy-intensive industries in agriculture and agribusiness. The reduction of environmental indicators reveals the linkages between economic activity and environmental problems, to some of which agriculture is an important contributor. Finally, the milk quota increase under a nitrogen restriction is an example of a simulation where the interaction between an agricultural and environmental policy is shown. The thesis aims to quantify policy effects at a detailed level, providing insight into the nature of the different environmental problems, the linkages between the economy and the environment, and the economic consequences of government intervention. In doing so, the results of the research can be useful for policy-makers and interest groups in the Netherlands in designing and evaluating policy.

The basic tool used in this thesis is a static, single-country applied general equilibrium (AGE) model for the Dutch economy, in which environmental relationships are explicitly incorporated. Given the linkages described and the economy-wide and trade effects that can be expected from agricultural and environmental policies, using an AGE for a small open economy model is appropriate (Hertel, 1990). Moreover, the availability of new environmental data at a very disaggregated level for the Netherlands makes it possible, and from a scientific point of view interesting, to link environmental data in a proper way to economic activity in an AGE model. Finally, an AGE model provides useful information on a variety of variables.

Numerous AGE models have been built over the last two decades to deal with a large number of policy issues (see for an overview e.g., Robinson, 1989; Gunning and Keyzer, 1995; and Shoven and Whalley, 1992). This thesis complements the existing AGE literature in several respects[2]. Firstly, the thesis analyses the economy-wide effects of specific environmental policies for agriculture in the Netherlands. Rendleman (1991) and Rendleman et al. (1995) look at the effects of reducing fertiliser and pesticide use in the United States (US). Hrubovcak et al. (1990) show the economy-wide effects of reducing the use of agricultural chemicals in the US. Komen et al. (1997) and Brockmeier et al. (1993) analyse the effects of reduced pesticide application for the Netherlands and Germany, respectively.

Secondly, there is scope for studies that analyse the effects of general environmental policies on agriculture in the Netherlands. Examples of AGE studies on general environmental policies in the Netherlands are Dellink and Jansen (1995) and Centraal Planbureau (1992 and 1993) that focus on the effects of an energy tax. Although agriculture as a whole is identified in these models, results are not distinguished for the individual agricultural industries. In addition, the effects on the environment are not analysed. Boyd and Uri (1991), Boyd and Krutilla (1992) and Boyd et al. (1995) are examples of AGE models for the US with four agricultural industries that analyse the effects of reductions in emissions of SO_2 and NO_x, SO_2 and CO_2 respectively. This thesis also contributes to bridging the gap that exists in the literature on empirical economy-wide analysis of the environmental effects of agricultural policies. Agricultural AGE model studies with a limited environmental component that are, however, not specifically directed towards analysing the effects of environmental policies in agriculture are for example Burniaux et al. (1990), Folmer et al. (1995), Harrison et al. (1995), Peerlings (1993), Hertel (1997) and SOW-VU (1998).

Finally, this thesis proposes a way of including emissions and indicators of environmental quality into an AGE model, linking emissions to inputs, output and consumption at a very detailed level. A high level of disaggregation is adopted with respect to industries that are the main contributors to environmental problems. The way of linking and the level of detail exploit the substitution possibilities that exist within an AGE model. In addition, an alternative way of technology specification is considered in which an industry is represented by a series of different technologies where each technology is characterised by a different emission-input-output mix. Using the mixed complementarity approach (see also Rutherford, 1995; Folmer et al., 1995; Gunning and Keyzer, 1995), technology switches are modelled that make it feasible to reduce emissions without necessarily reducing output.

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2 It is recognised that the literature on environmental and agricultural policy analysis is much broader than the AGE based contributions. Attention to some of this literature will be paid in the subsequent chapters.

1.3 Organisation

This thesis consists of seven chapters, starting with the introduction. Chapter 2 presents and discusses the AGE model and data used in this thesis. Since in the different policy simulations different modifications of the model and data are used, the description of the model will not be exhaustive. Modifications of the model, used in the different policy simulations, are dealt with in the relevant chapters. A complete description of the basic model is presented in appendices. The chapter also deals with the economic and environmental data used. Data obtained from own calculations (e.g., detailed environmental data and disaggregation of agricultural data) are summarised in appendices.

In Chapter 3, the focus is on a typical environmental policy directed at agriculture, of which economy-wide effects can be expected. The chapter analyses the effects on the Dutch economy of a reduction in livestock production. Such a reduction is seen as a possible solution to the environmental problems linked with the excess supply of minerals to the environment. In the policy simulations, it is assumed that the mineral surplus in the Netherlands can be avoided by reducing livestock production in pig and poultry farming. Assumptions about factor mobility and trade are explicitly dealt with by means of a sensitivity analysis. The analysis shows the economic effects on agriculture and the important linkages that are present with the rest of the economy.

Chapter 4 deals with a general environmental policy that also has consequences for individual agricultural industries. To achieve the CO_2 emission target that was the result of the Framework Convention on Climate Change (FCCC), in 1996 the Dutch government implemented an energy tax on fossil fuels for heating and electricity by households and 'small' energy users. Moreover, the revenues of the energy tax are used to lower the pre-existing distortionary taxes related to labour supply. The research shows the detailed environmental and economic effects of the current Dutch unilateral environmental tax reform with (partial) exemptions for particular energy users. Horticulture under glass is one of the exempted industries for the use of natural gas. Special attention is paid to the double-dividend argument that the introduction of a small environmental tax reform not only improves the environment but might also raise non-environmental welfare, due to an improvement in the efficiency of the tax structure.

The Dutch government has developed environmental policy targets, specified in terms of environmental indicators that measure phenomena like the greenhouse effect, acidification, eutrophication, and waste accumulation. Typically, each policy target entails a reduction in emissions that cause the environmental problem measured by the indicator. Chapter 5 analyses the environmental and economic effects of restricting these indicators, using a system of emission permits for the Netherlands. Agriculture is an important contributor to these environmental problems. The analysis focuses on the different effects of restricting single environmental indicators, the effects of restricting different environmental indicators simultaneously and the tradeability of emission permits. Although the policy simulations in this chapter are hypothetical, the main causal relationships linking the economy and the environment are quantified and shadow prices of restrictions on different environmental indicators are determined. Moreover, the relationships between the different environmental indicators are revealed.

Chapter 6 focuses on the environmental and economic effects of an agricultural policy change. It analyses the effects of an increase in milk quota in the Netherlands when nitrogen (N) emissions are restricted. The AGE model applied in this chapter is written in mixed-complementarity format (AGE-MC model), in which dairy farming is represented by a series of different Leontief technologies. Each technology is characterised by a different emission-input-output mix. Consequently, technology switches make it feasible to reduce emissions without necessarily reducing output, which would be the case if emissions were related to output using a well-behaved neoclassical production technology. Under the policy change, inactive N-extensive technologies in dairy farming might become active and (partly) replace N-intensive technologies.

Finally in Chapter 7, methodological issues and results are discussed and conclusions are drawn.

CHAPTER 2

MODEL AND DATA SPECIFICATION[1]

Abstract

This chapter presents the basic version of the applied general equilibrium (AGE) model and data used in this thesis. A complete description of the model is provided. The model contains a high level of disaggregation with respect to agriculture, related industries and commodities. It is possible to analyse various agricultural and environmental policy changes with the model developed. In particular the effects on inter-industry transactions, factor demand, income, trade and the environment can be determined. The model results are conditional on model and data characteristics that are typical for AGE models in general or for the specific model used in this thesis. Some of the specific model characteristics and limitations are discussed.

2.1 Introduction

The purpose of this chapter is to present and discuss the basic version of the applied general equilibrium (AGE) model and data used in this thesis. Since in the different policy simulations different modifications of the model and data are used, the description of the model in this chapter will not be exhaustive. Modifications of the model, used in the different policy simulations are dealt with in the relevant chapters. In Section 2.2, the basic version of the model is described. A complete description of the basic model can be found in appendices. Section 2.3 deals with the economic and environmental data on which the simulations in this thesis are based. Data obtained from own calculations (e.g., detailed environmental data and disaggregation of agricultural data) are summarised in appendices. Finally, Section 2.4 provides a discussion of some specific characteristics of the model and data that are relevant for the simulations in this thesis.

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1 This chapter is partly based on Komen and Peerlings (1996).

2.2 Description of the AGE model

The model used in this thesis is a static, single-country AGE model of the Netherlands. In this section the theoretical background and the most relevant characteristics and assumptions of the model will be elaborated. Equations mentioned between parentheses correspond to the complete mathematical representation of the model, given in Appendix I. A discussion of some specific characteristics of the AGE model is postponed to Section 2.4.

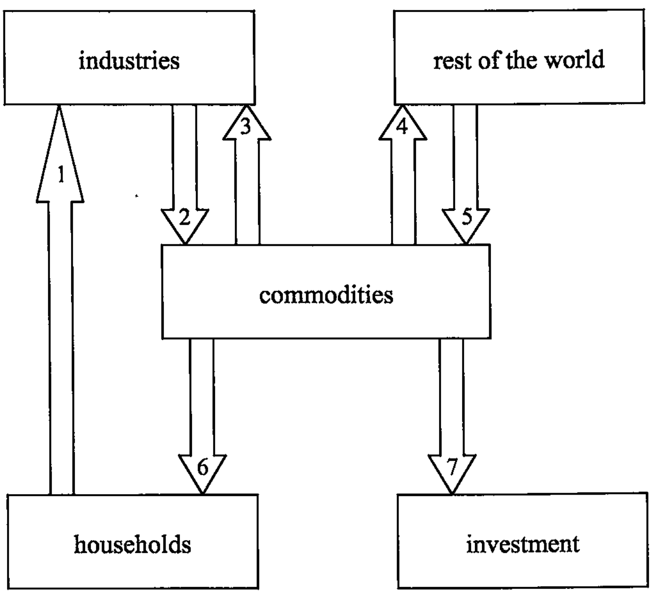
2.2.1 Theoretical background and general structure

A general equilibrium model is a model in which markets for each commodity and factor in an economy are specified and consistent optimisation by agents occurs as part of the equilibrium. Households maximise utility subject to their budget constraints, leading to the household demand for commodities and supply of factors. Market demands for commodities and factor supply depend on all prices, are continuous, non-negative, homogenous of degree zero in prices and income and satisfy Walras' Law. That is, at any set of prices, the total value of household expenditure equals household income or, stated differently, the value of excess demands equals zero at all prices. Producers maximise profits, leading to the demand for factors and commodities (inputs) and the supply of commodities (outputs). In equilibrium, prices are such that the required equilibrium conditions hold. Demand equals supply for all commodities and factors (Walrasian equilibrium), and in case of constant-returns-to-scale production technology, zero-profit conditions are satisfied for each industry. Zero homogeneity of demand and supply in prices implies that only relative prices are of any significance in such a model. Hence, a price numéraire has to be chosen to determine the actual price level. A discussion of general equilibrium theory can be found in most advanced micro-economic textbooks (for example Mas-Colell et al., 1995) or in more specialised literature (Ginsburgh and Keyzer, 1995).

The aim of AGE modelling is to convert the above-described Walrasian general equilibrium structure from an abstract representation of an economy into realistic models of actual economies. The idea is to use these models to evaluate policy options. The advantage of AGE models is that a computer removes the need to work in small dimensions and thus much more detail and complexity can be incorporated than in simple analytical models (Shoven and Whalley, 1984 and 1992). For a more exhaustive discussion of AGE models see Shoven and Whalley (1992), Gunning and Keyzer (1995) and Robinson (1989). A discussion of dynamic models, multi-country (trade) models and models with scale economies and imperfections in commodity or factor markets lies outside the scope of this thesis. There are several surveys on these topics, including Gunning and Keyzer (1995) on dynamics and imperfect competition, Shoven and Whalley (1984) on multi-country models and Devarajan and Rodrik (1989) and Harris (1984) on imperfect competition and scale economies.

2.2.2 Specification of the model

In an AGE model as applied in this thesis, the whole economy is modelled explicitly. The flows of commodities and factors of production in the AGE model used in this thesis are presented in Figure 2.1.



1. Factor demand
2. Output
3. Intermediate input demand
4. Exports
5. Imports
6. Household demand
7. Investment demand

Figure 2.1 *Flows of commodities and factors in the AGE model*

Industries produce output (2) using intermediate inputs (3) and factor inputs (1). Commodities produced (or imported (5)) can be exported (4), used as an intermediate input (3), consumed by households (6), or used as an investment good (7). Opposite to the flows of commodities and factors go expenditure and income flows (not shown in Figure 2.1)

Producer behaviour

In the model (see Appendix I) aggregate output in each industry is produced according a nested production structure (see Figure I.1 in Appendix I) using Constant Elasticity of Substitution (CES) production functions with constant returns to scale. The nested production structure applied in the model is rather standard (see: Shoven and Whalley, (1992), for an overview of studies using alternative nesting structures; Kemfert, (1998), for tests among different nests of capital, labour and energy). To emphasise the substitution possibilities between intermediate energy inputs, a separate nest has been chosen for intermediate energy and materials inputs. Hence, the aggregate output is composed of three hypothetical aggregate inputs: aggregate energy input, aggregate materials input and aggregate factor input. The energy aggregate consists of electricity and fossil fuels (other than fuels for vehicles) while the materials aggregate consists of all other intermediate inputs and fuels for vehicles[2]. The aggregate factor input is composed of labour and capital. Labour in the agricultural industries is composed of mobile (hired) labour and immobile (self-employed) labour. Labour in the non-agricultural industries is assumed mobile. Cost minimisation yields the demand functions for aggregate inputs (I.1, I.2 and I.3), intermediate energy inputs (I.4), intermediate materials inputs (I.5), factors (I.6), mobile labour (I.7 and I.9) and immobile labour (I.8) by industry.

From the aggregate output, individual commodities are produced according a Leontief product transformation function (I.10). This specification allows for an industry to produce more than one commodity and one commodity to be produced by different industries. This approach is preferred above the more standard approach where industries and production have a one to one relation because the latter contradicts reality. Total domestic production of each commodity is obtained by aggregation over industries (I.11).

CES functions are rather restrictive to describe the production structure of the Dutch economy (see: De Boer, 1981; Lesuis, 1991). Functional forms that are less restrictive than CES functions are for example the Constant Difference of Elasticity (CDE) function (see

2 Hence, fuels for vehicles that is related to transportation are considered not to be direct substitutes for the other fossil fuels and electricity.

Hertel et al., 1991) or the translog function (see Nakamura, 1984). Using these functional forms, however, requires more parameters to be specified which are not available at the aggregation level applied in this thesis. Moreover, flexible functional forms like the translog function cannot deal with large changes since global convexity is then no longer assured (see Chambers, 1988, p.177).

Trade

In the model the Armington assumption for modelling trade is used (see de Melo and Tarr, 1992, ch.2; Shoven and Whalley, 1992, ch.9 and de Melo and Robinson, 1989). The Armington assumption states that commodities imported and exported are imperfect substitutes of domestically produced and used commodities. The Armington assumption is adopted to be able to deal with two-way trade that is present in the observed trade statistics at the aggregation level used in the AGE model. Moreover, it avoids specialisation, which, following the law of comparative advantage, will generally result in only as many commodities being produced under free trade as there are factors of production (de Melo and Robinson, 1985).

The imported (exported) and domestically produced (demanded) commodities are (dis) aggregated into new composite commodities using constant returns to scale CES (Constant Elasticity of Transformation; CET) functions. Cost minimisation yields CES demand equations for domestic production (I.12) and imports (I.13) and revenue maximisation yields CET supply equations for domestic use (I.14) and exports (I.15). Hence, the levels of imports and exports depend on domestic and world market prices and the degree of substitutability between domestic and foreign commodities.

The consequence of a high level of disaggregation for agriculture is that some commodities can be distinguished that are internationally homogeneous. For these commodities, which have small import or export shares, the Armington assumption is not valid. Consequently, homogeneity is modelled by defining net trade as the difference between domestic production and domestic use (I.16). In this thesis, the homogeneity assumption is applied for the trade in pigs and eggs.

Import supply and export demand are assumed to be perfectly price elastic which implies that world market prices are constant (I.38, I.39 and I.40). Hence the Netherlands is treated as being a small country and is assumed to have no effect on world market prices. This implies that national policies will not entail terms of trade effects. With respect to the rest of the world, a fixed net trade surplus is assumed (I.64) while equilibrium is achieved by an endogenously determined exchange rate. Although a fixed exchange rate might better reflect the current economic situation for the Netherlands, a fixed net trade surplus is preferred to make the welfare analysis more transparent. Given that world market prices are also fixed, a fixed net trade surplus implicitly means that foreign welfare is fixed[3].

Factor supply

In the model, two factors are distinguished: capital and labour[4]. Total capital supply is perfectly price inelastic[5]. Total labour supply is price-elastic through a labour leisure choice (see household behaviour). In agriculture, self-employed labour is assumed immobile.

With respect to factor mobility there are two extreme possibilities (see also Kilkenny and Robinson, 1990). The first extreme is to assume industry specific factors (as is the case for self-employed labour in agriculture). The second extreme is to assume perfectly mobile factors. Perfect factor mobility equalises factor rewards between industries. The first approach is relevant in a short-term model, the second in a long-term model. In this thesis an intermediate approach is assumed: factors are imperfectly mobile (see Keller, 1979; Cornielje, 1990; Peerlings, 1993; Rendleman et al., 1995). Hence, factor prices differ between industries. Factor supply to industries is modelled using CET supply functions resulting from revenue maximisation (I.17 and I.18). The degree of factor mobility is determined by the magnitude of the transformation elasticity. Revenues from labour supply determine labour income (I.49). Gross capital income (I.50) corrected for a proportional capital depreciation (I.52) equals net capital income (I.51).

Household behaviour

There is one representative private household whose income (I.53) is given by capital income, labour income and domestic income transfers[6] corrected for income taxes, expenditures on leisure[7] and the balance of exogenous income transfers with the rest of the world (e.g., income from foreign assets). Future consumption (savings), leisure and current

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3 The welfare change expressed as the change in the value of trade using base year prices is zero when world market prices and the trade surplus with the rest of the world are assumed to be fixed.

4 Land is not considered as a third factor (see also discussion in Section 2.4).

5 In the static model used in this thesis it is assumed that investments entail a spending effect but no capacity effect. Moreover, capital is assumed immobile internationally. Hence, the total capital stock is assumed fixed.

6 Domestic income transfers are mainly social security benefits, paid lump sum by the government to households.

7 Employment and leisure are calibrated by assuming an unemployment rate (including voluntary unemployment) of 20 per cent.

consumption determine the private household's welfare according a nested CES utility function. In the first stage of the multi-stage budgeting (see Deaton and Muellbauer, 1980), a choice is made between future consumption (savings) and a composite of leisure and current aggregate consumption (I.54 and I.55). In the second stage, the budget is divided into leisure and aggregate consumption (I.56 and I.57). Total labour supply (I.58) hence results from a labour leisure choice and is price elastic[8]. In the last stage, expenditure on current aggregate consumption is divided into demand for individual commodities according CES uncompensated demand functions (I.19).

The multi-stage budgeting is rather standard when leisure and savings are taken into account in the utility function (see Shoven and Whalley, 1992). The disadvantage of CES-demand functions is that income elasticities for all commodities are equal to one. Although other functional forms (e.g., LES-AIDS: see Michalek and Keyzer, 1992; Folmer et al., 1995; LES-CES: Peerlings, 1993) would make the model less restrictive, selecting parameters of these functions requires more data and will enlarge the model significantly. Since the focus of this thesis is mainly on industries, the more simple CES function is chosen.

Government behaviour

The model incorporates the most important features of the Dutch tax system (product-related indirect taxes and subsidies, non-product related taxes and subsidies, value-added taxes, labour taxes (employer's and employee's share), a capital tax (tax on dividends and corporation tax) and an income tax. Tax revenue (I.59) corrected for the balance of income transfers with the rest of the world (e.g., development aid) and a government deficit[9] (I.60) determine the government budget (I.61). The government budget is proportionally divided over domestic income transfers and expenditures on public goods (I.62). Government demand is modelled by CES uncompensated demand functions (I.20).

Investments

Total gross savings in the economy equal the sum of private savings and capital depreciation corrected for the government deficit and the surplus on the balance of trade. The model has a neo-classical closure rule in the sense that total savings, corrected for non-product related

8 In the model the substitution elasticity between leisure and consumption is chosen such that the uncompensated elasticity of labour supply with respect to the wage rate is positive, i.e. the substitution effect dominates the income effect.

9 The government deficit is assumed to be a fixed percentage of the total government budget.

taxes on investment (e.g., investment subsidies) determine investment (I.63). In case saving is seen as buying a capital good by households, the government and the rest of the world to store wealth, investment demand for individual commodities is the input demand of a hypothetical capital goods industry that produces this (aggregate) capital good (see Keller, 1979; Cornielje, 1990; Peerlings, 1993). This neo-classical closure rule implies that investments (savings) only have a spending effect, but no capacity effect. Investment demand is modelled using Leontief input demand functions (I.21). Leontief instead of CES input demand functions are used because in the initial situation, demand is sometimes negative (reduction of stocks).

Equilibrium conditions and price equations

In a general equilibrium model, all input and output markets are in equilibrium. Hence, total domestic use equals the sum of intermediate, private household, government and investment demand (I.48). The same equilibrium conditions are implicitly assumed at the markets for factor inputs, imports, exports and investment. In addition to these market equilibrium conditions, zero profit is assumed, implying that the value of the inputs equals the value of outputs (I.22 up to and including I.32). Homogeneity of the production and transformation functions concerned (CES, CET and Leontief) guarantee that the zero profit conditions hold.

Market margins (trade and transportation services) are produced by different industries. The use of these market margins (I.33 and I.34) is incorporated in the buyers' prices of each commodity at three levels in the model: exports (export margins), total domestic use (wholesale margins) and household demand (retail margins). At each level a constant market margin rate for each commodity is assumed, being the share of market margins in the value of the transaction at sellers' prices. Indirect taxes and price reducing subsidies are incorporated in the buyers' prices, creating, together with the market margins, a price wedge between sellers' and buyers' prices (I.35 up to and including I.40). Indirect non-product related taxes, value added taxes and direct taxes also drive a wedge between the buyers' and sellers' price of total private consumption (I.41), investments (I.42), aggregate factor input (I.43) and factors (I.44 up to and including I.47).

Because in the AGE model all equations are homogeneous of degree zero in prices, a price numéraire has to be chosen to determine the actual price level. Since the focus of the thesis is mainly on industries, the Laspeyres index in output prices is chosen as price numéraire (I.65). Hence, price changes as result of policy simulations have to be considered relative to this price index.

Environment

The model includes nine emissions to take environmental effects of policy simulations into account (I.66). In order to represent a clear relation between emissions and economic activity, emissions should be dependent on quantities. In this thesis, emissions are assumed to be linked to intermediate inputs, outputs, consumption of specific commodities and aggregate consumption. Nine different emissions are taken into account: carbon dioxide (CO_2), nitrogen oxides (NO_x), sulphur dioxide (SO_2), nitrous oxide (N_2O), methane (CH_4), ammonia (NH_3), nitrogen (N), phosphate (P) and waste. The link of emission data to the economic data is discussed in Section 2.3.3.

Welfare

AGE policy analyses generate a wide range of outcomes, for example changes in emissions, inter-industry transactions, factor demand, income, trade and tax revenues. Moreover, AGE models are especially suitable for welfare analysis given that all households, commodities and factors are explicitly modelled. Usually the equivalent variation (EV) can be used as a welfare measure if utility maximising behaviour is considered. The EV is the difference in expenditures on a household consumption bundle between optimal utility levels in two equilibria (e.g., before and after a policy change), using the prices of the initial equilibrium. With other words, the EV asks (Shoven and Whalley, 1992, p.125): "How much money is a particular change (that has taken place between equilibria) equivalent to?" In the model used in this thesis, the EV can be derived at all (sub) utility levels of the multi-stage budgeting by the private household (I.67, I.68 and I.69) and the government (I.70).

A disadvantage of using the equivalent variation in the AGE model in this thesis is that it does not account for the welfare effects of savings that are not explicitly the result of optimising utility (i.e. capital depreciation, government deficit and the balance of trade). Hence, the equivalent variation would represent the welfare change of the whole economy only if those savings had been held constant. An alternative welfare measure, for example suggested by Dervis et al. (1982) that is used in this thesis, is the Laspeyres measure of real income change. This measure compares commodity bundles between two equilibria (e.g., before and after a policy change), using the prices of the initial equilibrium (I.71)[10]. This welfare measure has the advantage that it allows for the calculation of the welfare effect of savings

[10] A necessary condition for welfare to have improved is that the Laspeyres index of real income increases. In general, the Laspeyres index of real income will constitute an 'upper bound' to the underlying change in welfare (Dervis et al., p. 242-243).

other than the private savings of which the underlying optimising behaviour is not modelled explicitly.

2.3 Data specification

The purpose of this section is to discuss the data that form the basis for the model applications in the subsequent chapters. In Section 2.3.1, the Social Accounting Matrices for 1990 and 1993 are presented. Section 2.3.2 presents the make and use tables that represent the origin and destination of commodities. Special attention is given to the elimination of hidden data, the disaggregation of agriculture and the meat industry, and the disaggregation of margins and indirect taxes/subsidies. Section 2.3.3 describes the construction and incorporation of environmental data. Finally, Section 2.3.4 deals with elasticities and calibration issues.

2.3.1 Social Accounting Matrices

The data for an AGE model can be presented in a Social Accounting Matrix (SAM). A SAM is a square matrix that represents the transactions in an economy, in which for every income there is a corresponding outlay or expenditure. The matrix is structured such that each transactor or group of transactors has its own row and column, where rows and columns are identically ordered. By convention, receipts recorded by origin are entered in rows and expenditures by destination are entered in columns (Pyatt, 1988). The totals of the rows (the receipts) equal the totals of the columns (payments). As the basis for the SAMs that show the transactions and income flows in the Dutch economy in 1990 and 1993 (see Appendix II), aggregated national accounts matrices are used (CBS-1, various years and Keuning and de Gijt, 1992). To be compatible with the AGE model, the SAM is adjusted in several respects. Complex transactions due to income redistribution or financial sectors, which are not part of the AGE model, are simplified or aggregated. In addition, mutual lump-sum transfers between transactors are cancelled out. Relevant tax transfers, however, are maintained since they represent distortions in the economy that are modelled accordingly.

2.3.2 Make and use tables

The main part of the SAM is formed by make and use tables. A make table shows the origin of the commodities that are distinguished in the model: domestic industries and imports. A use table shows the destination of the commodities: domestic industries, private and public consumption, investments and exports. This representation of the input-output structure in the SAM is different from usual SAMs because there is no one to one relation between industries and outputs. Dairy farming, for example, is producing six different outputs. Moreover, commodities can be produced by more than one industry. Dairy products, for example, are produced by the dairy industry but also by dairy farming. To construct make and use tables compatible with the AGE model used in this thesis, several additional data manipulations and calculations are pursued. In this section, the most important issues are dealt with, i.e. the elimination of hidden data, the aggregation level of industries and commodities, and the division of margins and indirect taxes/subsidies.

Elimination of hidden data

Since the focus of the model is on agriculture and related industries, a high level of disaggregation is desired with respect to these industries. For this purpose, use is made of so called 'extended' make and use tables (CBS-3, various years), in which a more disaggregated level is applied than in the data that has been published officially (CBS-2, various years). However, the disadvantage of the extended data sets is that the tables contain hidden rows (commodities) and columns (industries). These hidden table entries are created in order to hide particular industries and commodities that could be identified easily when just a few large suppliers of certain commodities are active. Some hidden industry-commodity entries, however, for which a clear one to one relation exists, can be eliminated (see Appendix III for the procedure). Using this procedure, in the make and use table of 1990, 41550 (84%) and 959 (56%) mln guilders (1990), respectively, on hidden data are eliminated. For 1993, these numbers are 28910 (85%) and 1277 (68%) mln guilders (1993), respectively. The most important elimination for agriculture concerns the elimination of hidden output data of the fertiliser industry (1889 mln guilders in 1990 and 1403 mln guilders in 1993).

Aggregation level of industries and commodities

The original data set of about 230 industries and 650 commodities is aggregated into a smaller data set of 37 industries and 45 commodities in which agricultural and food commodities ana industries are dominant. In addition, special attention is paid to highly polluting industries, energy producing and distributing industries and energy sources (see Appendix IV for a list of commodities and industries). The energy sources distinguished in the model include coal, raw materials energy (e.g., crude oil), fuels for vehicles, natural gas, distributed gas, other fuels for heating and electricity. The only agricultural industry that was present in the original data set is disaggregated into six different agricultural industries, i.e. dairy farming, pig farming, poultry farming, arable farming, horticulture under glass and other horticulture. This subdivision is made because of the different features of the agricultural industries, which are relevant, when policy simulations are performed. A limitation of this procedure is, however, that agriculture is specified as six specialised industries. In reality, part of agricultural production is observed on mixed farms. To avoid peculiar model results, the single meat industry present in the original data set is also disaggregated in three meat industries: poultry meat industry, pig meat industry and beef and other meat industry[11].

Although subdivision of the make table is rather straightforward (e.g., milk is produced by dairy farming, pigs by pig farming etc.), subdivision of the use table requires additional information. The cost structure of the distinguished industries is revealed using data from various sources (LEI/CBS, various years; LEI, various years; CBS-2, various years; CBS-4, 1993; CBS-5, 1991; Konijn and de Boer, 1994; IKC, 1991; and PMVO, 1995). The make and use tables for 1990 and 1993 are summarised in Appendix V. Agricultural and meat industries are fully represented in these tables.

In agriculture, production and prices can be volatile due to, for example, uncontrolled natural factors. Hence, the use of a data set for a single year could give untypical estimates for cost and revenue shares, and therefore for elasticities in the model (see also Adams, 1987). In addition, when output prices are low, a negative residual factor income might result. Although average cost and revenue shares for a number of years could solve these problems, this approach needs significant additional data efforts and is not applied in this thesis.

Margins and indirect taxes/subsidies

The supply of commodities (make table) is valued in sellers' prices and c.i.f. import prices. The demand of commodities (use table) is valued at buyers' prices and f.o.b. export prices. The

[11] Consider the case of one meat industry, processing all types of meat. If, for example, a specific policy reduced output by pig farming, it might be the case that due to less input of pigs, the single meat industry reduces output and thereby also the input of poultry. Indirectly this might lead to a reduction of poultry farming.

difference in valuation between the make table and use table consists of the market margins and the indirect product-related taxes and subsidies. These market margins and indirect taxes/subsidies are included in the make tables (see Tables V.1 and V.3), which ensures equality between the totals of the make and use tables. It is not known to which transactions market margins and indirect taxes/subsidies are related. However, using additional data (CBS-1 and CBS-2, various years) market margins can be distinguished at three levels: export (export margins), total domestic use (wholesale margins) and household demand (retail margins). Equally, product-related taxes and subsidies are distinguished for exports, total domestic use and imports (see Appendix VI for the margin and tax tables for 1990 and 1993).

2.3.3 Environmental data

In this thesis, emissions are defined as the net discharge of substances that contribute to a commonly recognised environmental problem. For example, nitrogen and phosphate emissions contribute to eutrophication. In agriculture it should be taken into account that part of the nitrogen and phosphate discharge by livestock does not contribute to emissions since it is utilised by crops.

The emission data used to extend the economic model (see Appendix VII) are taken from the National Accounting Matrix including Environmental Accounts (NAMEA) for the Netherlands (see for a discussion: de Haan and Keuning, 1996). To be useful, the emission data from the NAMEA (CBS-6, 1996) are adjusted to the level of aggregation of the model[12]. Moreover, since emissions are not modelled as economic inputs, emissions have to be related to the relevant variables that are present in the economic model.

In this section, the emission matrix is described for 1993 (see Tables VII.6 to VII.12). Due to lack of information at the time of composing, the emission matrix for 1990 is slightly different and less detailed. Several additional data sources are used to compose the emission matrices (CBS-7, 1992; CBS-8, 1993; CBS-9, various years; CBS-10, various years; CBS-11, 1997; CBS-12, various years; CBS-13, 1992; MVROM, 1995).

CO_2, NO_x, SO_2, N_2O and CH_4 emissions (see Tables VII.6 to VII.10) are related to three

[12] The totals of the emission matrix presented in this section are exactly equal to the totals presented in the officially published NAMEA for most emissions. However, since it was discovered that a significant systematic error was made in the accounting of the N and P statistics for agriculture, these emissions are adjusted in the 1993 emission matrix. A mineral balance for N and P is composed for each agricultural industry to determine the surplus of these emissions (see appendix VIII). Communicating this error with the data source (Centraal Bureau voor de Statistiek, Netherlands) resulted in adjustments for these statistics since 1999.

different types of sources: processes, burning of fossil fuels in stationary sources and burning of fossil fuels in mobile sources. Process emissions are not related to a specific commodity but result from the technical production process as a whole. In the model, such emissions are assumed proportional to output by industries. Emissions that result from the burning of fossil fuels in stationary sources in production and consumption are assumed to be proportional to the use of natural gas, distributed gas, coal and/or other fuels used for heating, using different emission coefficients by energy source and industry. Emissions resulting from mobile sources are assumed to be proportional to fuel use by vehicles as well for consumers as for industries.

N emissions (Table VII.11) are also related to three types of different sources: air emissions, water emissions and soil emissions. N emissions to the air originate from NO_x and NH_3 emissions and hence are indirectly dependent on the variables to which these emissions are related. N emissions to water mainly originate from sewage that is assumed to vary with output in industries and aggregate consumption. N emissions to the soil, including nitrogen leaching to the groundwater, are relevant in agriculture. For each agricultural industry, a mineral balance for nitrogen is composed to determine the mineral emission (see Appendix Figure VIII.1). Part of the N emissions are linked to input of fertiliser and part is related to the production of manure that is linked to output[13].

For P emissions (Table VII.11) also a distinction is made between water and soil emissions. P emissions to water are assumed to be related to consumption and intermediate input use of cleaning products. P emissions to the soil in agriculture are calculated identically as N emissions (see Appendix Figure VIII.2).

Emission of NH_3 and waste (Table VII.12) are assumed to be related to output by industries and aggregate consumption by consumers. Finally, part of the NH_3 emissions in agriculture is related to the input of fertiliser.

2.3.4 Elasticities and calibration

The parameter values of the functions are crucial in determining the results of policy simulations generated with AGE models. The procedure to select parameter values is called calibration. The parameters of the model are chosen such that the economy under consideration is assumed to be in equilibrium, a so-called 'benchmark' equilibrium. Because the benchmark data only give price

[13] The nitrogen originating from N_2O and N_2 due to denitrification from the soil is not included in the nitrogen emissions to the air, since the determination of these emissions is still uncertain (CBS-10, 1997). Hence, nitrogen emissions to the soil are slightly overestimated.

and quantity observations associated with a single equilibrium, estimates of elasticities are also required. The specification of elasticities can be thought of as determining the curvature of isoquants and indifference surfaces, with their position given by the benchmark equilibrium data. The parameter values that are generated by the benchmark data and elasticities can then be used to solve for alternative equilibria associated with different policies, so-called 'counterfactual' equilibria.

If the parameters in the model had been estimated by econometric methods, econometric tests could be used to validate the model. However, this is not possible if parameters are selected by calibration. Sensitivity analysis has to provide insight in the correctness of the model specification and the sensitivity of the model results for different values of the exogenous variables and substitution and transformation elasticities (see Harrison et al., 1993). Few researchers have tried to evaluate the performance of their AGE model (for an exception, see Kehoe and Sancho, 1991).

In the model CES production and CET product transformation functions are used which implies that substitution and transformation elasticities (see Appendix IX) have to be specified exogenously (Shoven and Whalley, 1992). Most of the substitution and transformation elasticities used in this thesis for the production, consumption and trade functions are directly taken from Zeelenberg et al. (1991). However, since the industry and commodity division do not match, some adjustments are necessary. When in the AGE model two or more industries (commodities) are aggregated for which different elasticities are valid, a new elasticity is calculated by aggregating the original elasticities using the share of the individual industries (commodities) in the relevant CES or CET composite as weights. The substitution and transformation elasticities for trade in agricultural and meat products are chosen to be higher than the elasticities reported in Zeelenberg et al. (1991), since for these commodities a higher level of disaggregation is applied. At the level of aggregation applied in this thesis, substitution and transformation elasticities are not available from the literature. Transformation elasticities used to indicate labour and capital mobility are based on own approximations. The sensitivity of the model results with respect to trade elasticities and factor mobility is analysed in sensitivity analyses in various chapters.

The different simulations in this thesis are based on an AGE model that is calibrated using data for 1990 or 1993. Due to changing definitions and developments in data accounting (e.g., the relatively recent collection of environmental data), the data of the different years are not perfectly comparable. In addition, it is recognised that the outcomes of the model should be interpreted carefully when 'old' data are used. Although a more recent data set would increase the policy relevance of the model results, additional investments in another data set do not take priority in this thesis.

2.4 Discussion

The purpose of this chapter is to present a static AGE model for the Netherlands. It is possible to analyse various agricultural and environmental policy changes with the model developed. In particular the effects on inter-industry transactions, factor demand, income, trade and the environment can be determined. The model results are conditional on model and data characteristics. Some of them are model specific; some are typical AGE model features. Discussions on general AGE model characteristics like the specification of agents, dynamics and equilibrium conditions can be found in Gunning and Keyzer (1995), Shoven and Whalley (1992) and Peerlings (1993). This section discusses some of the specific characteristics and limitations of the way factor markets, trade and the environment are calibrated and modelled, which are relevant for the simulations in this thesis.

Factor markets

In the basic model, two factors of production are distinguished: labour and capital. Labour income is determined statistically by wages including social premiums that is paid for hired labour. Capital income is usually determined as a residual income. This would imply, however, that the reward for self-employed labour is part of capital income. Since self-employed labour is an important immobile factor of production in agriculture, it is distinguished from capital income in the model. Using a market-based reward for capital, immobile self-employed labour is the residual factor income[14]. A third factor of production that could be distinguished in agriculture is land. If land were distinguished from the other factors using market prices, however, a negative residual factor income would result. Since it is not necessary to consider land as a separate factor in the model simulations in this thesis, it is considered as part of the factor capital.

Total capital supply is exogenous in the model, which has important implications when

[14] This same reasoning can be made for self-employed capital on farms that is, at least in the short term, immobile. In fact, in the data set for 1993 self-employed capital was considered as part of the immobile factor input to avoid a negative reward (as result of low output prices in pig farming that year). The immobile factor input in agriculture in 1993 therefore included both self-employed labour and self-employed capital.

environmental policies are considered. In modelling saving and investment, the approach taken by Keller (1979) is followed. The private household buys an aggregate of (newly produced) capital goods as saving. In case the production of capital goods is energy intensive, the introduction of an energy tax will increase the price of aggregate capital. This has a negative effect on savings, since future consumption is more expensive. However, since in the static model investments only have a spending effect but no capacity effect, an energy tax will not affect the capital stock. Another implication of a fixed capital supply is that a tax on capital is not distortionary and hence equivalent to lump sum taxation.

Trade

The small country assumption implies that the Netherlands is assumed to be small on world markets and therefore cannot affect its terms of trade. This is relevant in this thesis when environmental or agricultural policies affect domestic prices. The Armington assumption, on the other hand, implies that domestic prices are no longer rigidly linked to world prices. Since introducing product differentiation violates the small-country assumption, Dervis et al. (1982) therefore call this a weaker form of the small country assumption in the sense that the assumption of fixed world market prices still holds. Dervis et al. (1982) also mention some different implications on the import and export side when the Armington assumption is combined with the small country assumption. As they argue, on the import side, the small country assumption implies that a small fraction of the market for commodities produced in other countries is constituted. Hence, the Armington assumption does not contradict the assumption of infinitely elastic foreign supply curves. Maintaining the small-country assumption on the export side, however, is quite different. When a country is selling a differentiated product, it may no longer be small in the market for that product. Hence, the demand for exports will be less than infinitely elastic and the small-country assumption no longer holds. Another implication of the Armington assumption on the export side is that output of different industries is assumed to be homogeneous domestically but heterogeneous when there is a choice between domestic use and exports. In this thesis, the problem of combining the Armington and small country assumption on the export side is partially solved by distinguishing commodities that are internationally homogeneous (see also Komen, 1995). These commodities are either exported or imported, which is revealed by trade statistics. Exports of other commodities are still modelled using the Armington assumption, since specifying export demand functions requires additional information on parameters, which is not available. For these commodities, an increase in domestic prices due to policy changes will partly be transferred to the rest of the world.

The specification of a single rest of the world is too restrictive when trade and trade policy analyses are considered explicitly. Given the importance of trade for the Netherlands, in that case a division into EU and the rest of the world has to be considered for all commodities, as is a more explicit modelling of world markets. The same holds when the EU Common Agricultural Policy (CAP) is considered. Taking all the CAP instruments into account requires a significant additional modelling and data effort for as well the instruments as the budgetary flows between the Netherlands and the EU (see for such an effort: Gohin et al., 1998; Jongeneel, 2000). Since the focus of this thesis is not primarily on EU CAP instruments or trade policies, they are not explicitly taken into account in the basic version of the model.

Environment

Since the environment is a central part of the model simulations in this thesis, the incorporation of emissions into the AGE model needs some attention.

Although emissions are taken into account at a very detailed level, there are still some improvements possible. Due to insufficient information, it is assumed that some emissions by industries are related to aggregate output, while it seems clear that part of it is related to certain inputs. In addition, not all the harmful emissions are taken into account (e.g., pesticides, dioxin, heavy metals, etc.). Moreover, abatement functions are not present in the model. In the basic model, a reduction of emissions can therefore only take place by reducing inputs and aggregate output by industries and consumer goods and aggregate consumption by consumers. In some other studies, abatement functions are taken into account based on ad hoc assumptions (e.g., Bergman, 1991; Verbruggen et al., 1999) or embedded in the SAM (e.g., Nestor and Pasurka, 1995). At the level of detail applied in this thesis, however, data is lacking to derive a consistent set of abatement functions for all emissions by all activities.

It is recognised that the emission numbers produced by the model simulations should be interpreted with care, due to the static and single country nature of the model. Emissions are considered as being flows while some emissions are only harmful after reaching a certain stock (e.g., the accumulation of phosphate into the soil). Moreover, international flows of emissions are not taken into account.

Finally, in the AGE model in this thesis, environmental quality is not part of the utility function of the households. Hence, the welfare measures do not take into account a welfare change resulting from a change in environmental quality. Different ways of incorporating environmental quality in welfare measures are possible. In what is called a 'net benefit analysis', Boyd et al. (1995) adjust the conventional welfare measures like the EV by monetary estimates of environmental benefits. Another approach is to incorporate environmental quality in the utility functions of the households. In the models by Piggott et al. (1992) and Perroni and Wigle (1994), the utility function is separable in commodities and environmental quality. Espinosa and Smith (1995), and Smith and Espinosa (1996) assume that the utility function of households is non-separable in commodities and environmental quality. In case of both separability and non-separability, additional information, for example expenditure on environmental quality, is required. For this purpose Espinosa and Smith (1995) and Smith and Espinosa (1996) make use of existing non-market valuation estimates of morbidity and mortality effects of several emissions. However, given the difficulty of obtaining good estimates, environmental quality is mostly omitted from welfare analysis, as is the case in this thesis.

CHAPTER 3

RESTRICTING INTENSIVE LIVESTOCK PRODUCTION: ECONOMIC EFFECTS OF MINERAL POLICY IN THE NETHERLANDS[1]

Abstract

This chapter examines the effects on the Dutch economy of a reduction in intensive livestock production using an applied general equilibrium model. A reduction is seen as a possible solution to the environmental problems linked with the excess supply of minerals to the environment. Results show that a decrease in pig and poultry production to achieve a maximum permitted phosphate loss of 30 kg/ha will decrease income of pig and poultry farming by 2.6 and 1.0 per cent, respectively. The compound feed, pig meat and poultry meat industry are seriously affected. Results for trade show a reduction in net exports of livestock and meat and a reduction in net imports of feed stuffs.

3.1 Introduction

The high level of agricultural support in the European Union (EU) has increased the use of feed imports and raised livestock densities. This has led to a high pressure on the environment through an excess supply of minerals (Koopmans, 1987; Bonnieux and Rainelli, 1988). This excess supply causes denitrification and leaching to the soil of phosphate and nitrogen, polluting surface water and ground water. The emission of ammonia from stables and manure spreading also contributes to acidification. Therefore, to an increasing extent, mineral policies are being implemented in the EU (Vermersch et al., 1993). A reduction in livestock production is a possible strategy.

Economic research on the consequences of mineral policies has focused mainly on the consequences at farm level (see among others: Fontein et al., 1994; Vermersch et al., 1993; Johnsen, 1993). Koopmans (1987) and Klaassen (1994) focused on the EU level while Nieuwenhuize et al. (1995) look at the national level in the Netherlands using an input-output

[1] This chapter is based on Komen and Peerlings (1998).

model. However, input-output analysis is not a useful tool for mineral policy analyses because it can only handle changes in final demand for livestock and it includes no price relationships. Moreover, an important aspect of reducing livestock production is the effect on production, income formation and employment both in livestock farming and other industries (e.g., compound feed and meat industries) but also on trade and welfare. Finally, there might also be feedback effects from outside the industries primarily concerned. If economy-wide consequences remain unidentified, the lack of knowledge may lead to less adequate policies. In order to deal with these economy-wide effects and to allow for price changes and substitution, using an applied general equilibrium (AGE) model is appropriate.

In this chapter, it is assumed that the mineral surplus in the Netherlands can be avoided by reducing livestock production in pig and poultry farming. In addition, a reduction in pig numbers alone is considered, since it might be argued that poultry production should not be reduced because the manure that is produced by this industry is more appropriate to export. Reducing dairy production is not considered because dairy farming has a relatively low production of phosphate per hectare and because of the self-regulating consequences of the milk quota.

Section 3.2 deals with mineral problems and policies in the Netherlands. Section 3.3 provides information on the model and data characteristics, as far as they differ from the version described in Chapter 2. Policy simulations are in Section 3.4. Some of the results are elucidated and discussed in Section 3.5. Section 3.6 provides a sensitivity analysis with respect to some critical parameters. Finally, in Section 3.7 a summary and conclusions are provided.

3.2 Mineral problems

In this thesis, livestock is divided into cattle and other animals, pigs and poultry. Dairy farming (milk, cattle and other animal production), pig farming (pig production) and poultry farming (poultry and eggs production) are the main suppliers of livestock. Of the total gross value added at factor cost generated by Dutch agriculture in 1990 (17,800 mln guilder) dairy, pig and poultry farming had a share of 32, 12 and 5 per cent respectively (see also Table V.2 of Appendix V).

Herd sizes increased during the 1970s and early 1980s (see Table 3.1). In 1984, the introduction of the milk quota system reduced dairy cow numbers. In the years after 1984, the national dairy herd decreased further because of additional quota reductions and an increased productivity of dairy cows. At the same time the number of suckler cows, fattening cattle and sheep increased because dairy farmers were looking for alternatives to milk production.

Table 3.1 *Composition of the Dutch livestock population (total numbers in 1000 heads)*

	Cattle	Pigs	Poultry	Sheep
1970	4314	5533	55400	575
1980	5226	10138	81155	858
1984	5516	11146	83368	766
1988	4710	13934	93127	1169
1992	4920	14161	99361	1954
1996	4551	14419	91441	1627
1997	4411	15189	93106	1465
1998	4283	13446	98692	1394

Source: LEI/CBS (various years).

The increase in livestock production (in particular pigs and poultry) was made possible by a growing international demand for animal products and a favourable EU (common) agricultural policy. Due to price support for cereals in the EU and the absence of import levies on imported feedstuffs, import of, for example, tapioca, soy, citrus pulp and maize gluten became attractive for Dutch farmers, who exploited their proximity to the port of Rotterdam. The positive trade balance in feedstuffs led, in turn, to surpluses of minerals, especially phosphate and nitrogen. These surpluses cause denitrification and leaching to the soil of phosphate and nitrogen, polluting surface and ground water. The emission of ammonia from stables and manure spreading also contributes to acidification.

In the 1980s and 1990s the Dutch government introduced some policies to reduce mineral problems (MLNV-2, 1995). One of these policies involved limiting the amount of phosphate from manure that can be produced (phosphate production rights) and applied to land[2], depending on soil type, land use and the period of the year. These limitations stimulated the processing of manure or its transport to areas with deficits. Moreover, restrictions on the ways manure is stored and applied on land aim to reduce the emission of ammonia. However, total production rights were set at a level higher than actual phosphate

2 The government chooses phosphate as a basis for its policy since the phosphate content of manure is rather stable, contrary to the nitrogen content. In other European countries the focus is more on nitrogen (Vermersch et al., 1993). However, due to European legislation with respect to drinking water, in the future a specific nitrogen policy in The Netherlands will also be required. If administratively set fixed proportions between manure and nitrate had been used, it would of course make no difference whether one focused on phosphate or nitrogen.

production. Therefore, they have proven to be not very effective in reducing the production of phosphate. Table 3.2 shows the development of the production of minerals by Dutch livestock.

Table 3.2 *Production of minerals by Dutch cattle, pigs and poultry (in mln kilograms)*

	1970	1980	1984	1988	1992	1996	1997	1998
Phosphate (P_2O_5)	170	230	254	238	221	192	190	189
Nitrogen (total N)	356	483	564	559	583	560	536	531
Potassium (K_2O)	401	534	623	619	644	614	599	588

Source: LEI/CBS (various years).

The Dutch government (TKSG, 1996) decided in 1996 to fix limits for permitted phosphate losses, instead of permitted phosphate use, per hectare. This permitted phosphate loss would be 40 kg/ha in 1998, 30 kg/ha in 2002, 25 kg/ha in 2005 and 20 kg/ha in 2010. The losses have to be calculated from a mineral (phosphate and nitrogen) bookkeeping system. In this system, the deliveries of minerals to the farm in the form of livestock, feed, manure and fertiliser, and the removal of minerals from the farm in the form of products and manure are recorded. The difference is the mineral loss for which a levy has to be paid (see also Oude Lansink and Peerlings, 1997)[3].

Given assumptions about distribution, exports and technological solutions (new feedstuffs and additives in feed) this would result in a national surplus in 1998 and 2002 of 8 mln and 18 mln kg phosphate, respectively (see Section 3.4). The government intended to let this surplus disappear by buying up phosphate production rights itself and siphoning off part of the production rights traded amongst producers.

3.3 Model characteristics

The model applied in this chapter is calibrated on the 1990 data set. This section gives a concise account of the model and data used for the analysis in this chapter. First, some differences in the main characteristics with respect to the basic version of the model described in Chapter 2 are provided. Secondly, this section deals with the specific adjustments of the model that are necessary for the simulations in this chapter.

3 Since the introduction of the mineral bookkeeping system, some adjustments were made. Currently (2000) the focus is not only on phosphate but also on nitrogen. In addition, the permitted mineral losses scheduled for 2010 are advanced to 2008. Although the use of fertiliser is not yet considered in calculating the levy, it will very likely be taken into account in the near future (MLNV-3, 2000).

3.3.1 General model characteristics

The model used in this chapter is slightly different from the model described in Chapter 2. The differences are dealt with in this section[4].

Firstly, in this chapter, aggregate output is composed of two aggregate inputs: an aggregate intermediate and an aggregate factor input. No distinction is made between an aggregate materials and an aggregate energy input.

Secondly, contrary to the basic version of the model, total labour supply is exogenous. In this chapter, a more simple two-stage structure is adopted to represent consumer preferences. In the first stage, private household income is distributed over household expenditures and savings according a Cobb-Douglas function. This implies that household expenditures, savings and non-product-specific indirect taxes (mainly VAT payments) form a fixed share of private household income. In the second stage, household expenditures are divided over individual commodities according CES uncompensated demand functions. These assumptions imply that there is no labour/leisure choice in the model. Hence, a change in leisure is also not taken into account in the welfare measure.

Finally, in the 1990 data set used in this chapter, emissions are not explicitly taken into account. Also, a less detailed aggregation level is applied for commodities and industries that are related to energy[5].

3.3.2 Supply quota in an AGE model

In this chapter, it is assumed that reductions in phosphate surpluses are induced by means of a supply quota for aggregate output by intensive livestock farming. A supply quota is a quantitative restriction on aggregate output. Since aggregate output is restricted a 'quota rent' occurs, which is equal to the difference between the market value and shadow value of aggregate output (see Hertel and Tsigas, 1991). It can be modelled equivalently as a variable ad valorem tax rate that induces a level of output, $\overline{Y_r}$, equal to the quota. The 'tax revenue' of such a tax equals the quota rent. The quota rent for each restricted industry r ($RENT_r$) enters

4 The model version used in this chapter was completed before the basic version of the model described in Chapter 2 that is slightly more complicated.

5 In this chapter, 38 commodities and 34 industries are distinguished. In the following chapters, where emissions are explicitly taken into account, more industries and commodities that contribute to emissions are distinguished.

the AGE model, ensuring that the zero profit conditions for restricted industries still hold. Hence, the zero profit condition in the basic model (equation I.22 in appendix I) is adjusted accordingly[6]:

$$WY_r.\overline{Y_r} \;=\; WAIN_r.AIN_r + WAPR_r.APR_r + RENT_r \qquad \forall r \in R \qquad (3.1)$$

with

$R \subset B$: subset of restricted industries.

The quota rent divided by output gives the price of the quota right per unit of output. If quota rights are tradeable, the quota price is a market or lease price. If quota rights are not tradeable, it is the shadow price of quota that is equivalent to the market price (see also Boots et al., 1997). In this chapter, quotas are assumed not tradeable. Since quota rents equal the difference between the value of output and inputs, they can be treated as an ordinary source of income for owners of the quota rights. In the model, quota rents are part of capital income. Hence, equation I.50 is replaced by:

$$I^{gcap} = WTPR_2.TPR_2 + \sum_{r\in R} RENT_r \qquad (3.2)$$

3.4 Policy simulations

In Table 3.3 national phosphate surpluses after exports (calculated in: MLNV-1, MLNV-2, (1995)) are used to calculate the reduction in pig and poultry production necessary to achieve a situation without surpluses. In calculating the surplus, it is assumed that the phosphate production per animal reduces in time due to technological improvements. Therefore, total production of phosphate decreases over time. Moreover, it is assumed that the production of phosphate by the dairy herd decreases, because the dairy herd becomes smaller. This is due to a combination of the milk quotas and an increase of the milk production per cow.

The phosphate balance sheet presented in Table 3.3, shows a surplus of 92 mln kg phosphate at farm level in the case of a permitted phosphate loss of 40 kg/ha in 1998. Of this surplus, 69 mln kg will be distributed to farms and areas with deficits, while 15 mln kg will

6 In this chapter materials and energy inputs are not distinguished. Hence, in equation (3.1) AIN_r is the single aggregate intermediate input of materials and energy.

be processed and exported. Hence, a permitted phosphate loss of 40 kg/ha results in a national surplus of 8 mln kg phosphate. Consequently, a reduction of 8.5 per cent in livestock numbers is necessary if pig and poultry production are both reduced by equal proportions, while a reduction of 12.5 per cent is necessary if only pig production is reduced[7]. When the environmental standard is tightened to a permitted phosphate loss of 30 kg/ha, reductions are 20.5 and 31.0 per cent, respectively. In the model, the reductions in phosphate surpluses are induced by means of a supply quota for intensive livestock. Quota rents are treated as a source of income for the industries concerned. To avoid an increase in phosphate production by poultry farming in the cases where only pig production is reduced, production by poultry farming is fixed at the base year level. Milk quota are taken into account by setting dairy production fixed at the base year level in all simulations.

Table 3.3 *Phosphate production, distribution and surplus (in mln kg phosphate) and calculated production reductions in 1998, 2002 and 2005*

Permitted phosphate loss per ha	40 kg (1998)		30 kg (2002)		25 kg (2005)	
Production	**200**		**190**		**185**	
- Dairy	106		102		100	
- Pigs	64		58		55	
- Poultry	30		30		30	
Surplus at farm level	**92**		**87**		**86**	
-/- distribution	69		49		49	
National surplus	**23**		**38**		**37**	
-/- processing plus exports	15		20		20	
National surplus after exports	**8**		**18**		**17**	
% reduction[a] in:						
Pigs and poultry	8.5	(=8/94)	20.5	(=18/88)	20.0	(=17/85)
Pigs	12.5	(=8/64)	31.0	(=18/58)	30.9	(=17/55)

[a] Own calculations.
Source: MLNV-1 (1995); MLNV-2 (1995), table 5.1.

3.5 Results

In this section the effects on production, income formation, commodity prices and trade for the Dutch economy of a reduction in pig and poultry production, necessary to achieve a situation without phosphate surpluses, are determined. The effects are calculated at different

[7] Hence, it is implicitly assumed that phosphate emissions are related to output. In later chapters, this assumption is relaxed when more information is used to relate emissions explicitly to both inputs and outputs.

levels of permitted phosphate losses. The results of a reduction in livestock production in the four different simulations are summarised in Tables 3.4 and 3.5.

Table 3.4 *Effects on trade and prices of selected commodities of reducing pig and poultry production (% change from benchmark)*

Variable[a]	Reduction pigs and poultry		Reduction pigs only	
Permitted phosphate loss (kg/ha):	40 kg	30 kg	40 kg	30 kg
Producer prices				
Pigs	0.2	2.3	0.2	5.7
Poultry	2.4	6.6	0.2	0.5
Eggs	0.2	0.5	0.2	0.5
Grain	-0.4	-1.0	-0.5	-1.1
Grain substitutes	-1.5	-3.6	-1.5	-3.7
Compound feed	-1.1	-2.6	-1.1	-2.7
Pig meat	0.2	1.3	0.2	3.3
Poultry meat	1.2	3.3	0.2	0.4
Export				
Pigs (966)	-53.4	-100.0	-78.6	-119.6
Poultry (223)	-16.1	-37.1	-0.0	-0.0
Eggs (743)	-12.7	-30.6	0.0	0.2
Grain (169)	-1.7	-4.0	-1.8	-4.2
Grain substitutes (1037)	-1.3	-2.9	-1.4	-3.0
Compound feed (917)	-0.7	-1.7	-0.7	-1.7
Pig meat (4546)	0.1	-7.0	0.1	-19.0
Poultry meat (1406)	-7.9	-19.6	0.1	0.2
Import				
Poultry (82)	1.0	3.8	0.0	0.0
Grain (1943)	-2.8	-6.5	-2.9	-6.9
Grain substitutes (1915)	-7.4	-17.0	-7.5	-17.6
Compound feed (383)	-10.9	-24.6	-11.2	-25.5
Pig meat (327)	-0.0	-2.3	-0.0	-5.3
Poultry meat (315)	-3.0	-7.1	-0.1	-0.2
Miscellaneous				
Balance of trade surplus (fixed at 19758)	0.00	0.00	0.00	0.00
Exchange rate (in 1990 guilders/dollar)	0.19	0.48	0.20	0.50

[a] Base year quantities, in mln 1990 guilders, between parentheses.

Table 3.4 shows that a reduction in pig production alone to achieve a permitted phosphate loss of 40 kg/ha does not lead (except for an exchange rate change) to a price change for pigs. The perfect homogeneity assumption equalises the domestic and export price. The fall in domestic production leads to a drop in exports of 78.6 per cent. If pig production alone is reduced to achieve a permitted phosphate loss of 30 kg/ha, the Netherlands becomes a pig importer. This shift leads to an increase in the domestic price (5.7 per cent), because it is the import price instead of the lower export price that determines the domestic price. There is a difference between the import (c.i.f) and export (f.o.b.) price because of market margins. When both pig and poultry production are reduced, in line with a permitted phosphate loss of 30 kg/ha, there is no trade in pigs. The domestic price happens to lie between the import and export price.

Table 3.5 shows that a decrease in both pig and poultry production, to achieve a phosphate loss of 30 kg/ha, will decrease income (including rents) in pig and poultry farming by 2.6 and 1.0 per cent, respectively. The small income decreases of pig and poultry farming result from the fact that reductions in income *excluding rents* of 42.9 and 40.8 per cent, respectively, are compensated for a large part by rents of 886 and 353 mln 1990 guilders, respectively. Income (including rents) and the size of the rents is determined by output prices and prices and use of intermediate and factor inputs. Prices of pigs and poultry production increase by 2.3 and 3.9 per cent, respectively, because pig and poultry supply falls. The price of the aggregate intermediate input is largely determined by the price of compound feed. This price falls because of the smaller demand for feed by pig and poultry farming. The price and use of the aggregate factor input is largely influenced by the degree of factor mobility and the substitution possibilities between the aggregate factor and intermediate input. The reduction in production leads to a smaller demand for the aggregate factor input. However, with a small degree of factor mobility, demand cannot fall much, which triggers a relatively large reduction in price. Due to substitution between the aggregate intermediate and factor input, in combination with low factor mobility, a reduction in production leads to a relatively large reduction in aggregate intermediate input use. If pig production alone is reduced to achieve a phosphate loss of 30 kg/ha, income (including rents) of pig farming will decrease by 4.8 per cent. In poultry and dairy farming, rents are created even without a reduction in production (quota levels are set at the old production level). This is caused by a fall in feed costs (compound feed prices fall) and a small increase in output prices.

The effects on factor input use, income and trade for the meat industry are strongly determined by the price of livestock and the availability of livestock, which is determined by domestic production (fixed at quota levels) and trade. For example, both the production and income for the pig meat industry hardly change at a permitted phosphate loss of 40 kg/ha, because the price of pigs does not change. However, at a phosphate loss of 30 kg/ha (reducing pigs only), production and income will fall by 13 and 15 per cent, respectively, due to the 6 per cent higher price for pigs. The effects on the compound feed industry are nearly independent of the way livestock production is reduced, because of the fixed relation between phosphate production and feed input.

Table 3.5 *Effects on the Dutch economy and selected industries of reducing pig and poultry production (% change from benchmark)*

Variable[a]	Reduction pigs and poultry		Reduce pigs only	
Permitted phosphate loss (kg/ha):	40 kg	30 kg	40 kg	30 kg
Quantity production				
Pig farming (7673)	-8.5	-20.5	-12.5	-31.0
Poultry farming (2558)	-8.5	-20.5	0.0	0.0
Compound feed industry (9283)	-5.7	-13.4	-5.9	-13.9
Pig meat industry (8814)	0.0	-4.7	0.0	-12.7
Poultry meat industry (2245)	-5.8	-14.5	0.0	0.1
Price production				
Pig farming	0.2	2.3	0.2	5.7
Poultry farming	1.4	3.9	0.2	0.5
Compound feed industry	-1.0	-2.3	-1.0	-2.4
Pig meat industry	0.2	1.3	0.2	3.1
Poultry meat industry	1.1	3.1	0.2	0.4
Quantity aggregate intermediate input				
Pig farming (5241)	-10.3	-24.1	-15.0	-35.7
Poultry farming (1596)	-10.3	-24.2	0.1	0.2
Compound feed industry (7485)	-6.0	-14.0	-6.1	-14.5
Pig meat industry (7209)	0.0	-5.2	0.0	-13.7
Poultry meat industry (1708)	-6.5	-16.0	0.0	0.0
Price aggregate intermediate input				
Pig farming	-0.7	-1.3	-0.8	-0.6
Poultry farming	-1.0	-2.5	-1.1	-2.7
Compound feed industry	-0.3	-0.8	-0.4	-0.9
Pig meat industry	0.2	2.0	0.2	5.2
Poultry meat industry	2.3	6.2	0.2	0.4
Quantity aggregate factor input				
Pig farming (2151)	-3.6	-9.1	-5.4	-14.5
Poultry farming (878)	-4.8	-12.1	-0.1	-0.3
Compound feed industry (1418)	-3.5	-8.4	-3.6	-8.7
Pig meat industry (1087)	0.1	-1.8	0.1	-5.3
Poultry meat industry (347)	-2.4	-6.2	0.1	0.2
Price aggregate factor input				
Pig farming	-17.1	-37.2	-24.2	-51.1
Poultry farming	-14.6	-32.7	-0.6	-1.5
Compound feed industry	-6.5	-15.2	-6.6	-15.7
Pig meat industry	0.1	-3.7	0.1	-9.9
Poultry meat industry	-4.7	-11.7	0.1	0.2
Income				
Dairy farming (5926)	-0.4	-1.0	-0.4	-1.1
Pig farming (2198)	-20.1	-42.9	-28.2	-58.2
Poultry farming (888)	-18.8	-40.8	-0.7	-1.8
Compound feed industry (942)	-9.8	-22.3	-10.0	-23.1
Pig meat industry (1169)	0.2	-5.4	0.2	-14.7
Poultry meat industry (367)	-7.0	-17.1	0.2	0.4
Income including rents				
Dairy farming (5926)	0.4	1.1	0.5	1.2
Pig farming (2198)	-1.8	-2.6	-4.1	-4.8
Poultry farming (888)	0.4	-1.0	2.5	6.2
Miscellaneous				
National income (516267)	-0.02	-0.09	-0.02	-0.14
Welfare[b]	-192.5	-623.9	-189.8	-795.5
Rent dairy farming[b]	50.2	125.9	51.7	135.0
Rent pig farming[b]	403.1	885.7	531.1	1173.8
Rent poultry farming[b]	170.3	353.4	28.6	71.2

[a] Base year quantities, in mln 1990 guilders, between parentheses.

[b] Welfare and rents in mln 1990 guilders.

Imports of grain substitutes and grain, used in the compound feed industry, fall. Dutch arable farming is only slightly affected (small reduction in production and income) because only a small part of its production is used in the compound feed industry (except for some grain and grain substitutes)[8]. Moreover, the lower prices for grain and grain substitutes have a larger effect on trade than on domestic production. Income in the compound feed and meat industries is relatively strongly affected, compared to the livestock industries, because of the absence of quota rents. In all cases, the exchange rate appreciates, which indicates that especially exporting industries are affected by the livestock reduction.

In the case of a permitted phosphate loss of 30 kg/ha when only pig production is reduced, welfare decreases by 800 mln 1990 guilders, which is only 0.15 per cent of national income. Columns 3 and 5 of Table 3.5 show that, from a welfare perspective, to achieve the same environmental goal, it is better to have a smaller reduction in two different industries than a larger reduction in one industry. It is important to note that these welfare reductions would be offset by environmental improvements, which are not included in the welfare measure.

3.6 Sensitivity analysis

A sensitivity analysis provides insight into the robustness of the model results for different values of the chosen parameters. This section contains a sensitivity analysis with respect to the trade substitution and transformation elasticities for agricultural and meat products (3.6.1), and factor transformation elasticities (3.6.2).

3.6.1 Trade substitution and transformation elasticities

The base simulations use trade substitution and transformation elasticities, for agricultural and meat products of 4.5 and 3, respectively. For trade in pigs and eggs, the homogeneity assumption is used. Columns 3 and 4 in Table 3.6 show the results for lower (3) and higher (4) trade substitution and transformation elasticities than in the base simulation (column 2) for meat products and agricultural products, except for pigs and eggs (where the homogeneity assumption is maintained).

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8 There is no effect on arable farming through manure trade since this market is not present in the national accounts and therefore not modelled.

Table 3.6 *Effects on the Dutch economy of reducing pig and poultry production at 30 kg/ha phosphate loss, using different trade elasticities (% change from benchmark)*

Variable[a]	Base case	Low trade elasticities[c]	High trade elasticities[d]	Armington assumption pigs
Production				
Pig meat industry (8814)	-4.7	-4.7	-4.8	-15.0
Mobile labour				
Pig meat industry (634)	-1.8	-1.5	-1.9	-6.2
Capital				
Pig meat industry (453)	-1.9	-1.6	-2.0	-6.5
Income				
Pig farming (2198)	-42.9	-43.3	-42.8	-42.5
Poultry farming (888)	-40.8	-41.5	-40.7	-40.9
Pig meat industry (1169)	-5.4	-4.7	-5.7	-17.4
Income including rents				
Pig farming (2198)	-2.6	1.8	-4.0	5.9
Poultry farming (888)	-1.0	7.0	-3.5	-1.0
Producer prices				
Pigs	2.3	3.2	2.0	6.1
Poultry	6.6	11.1	5.2	6.6
Grain	-1.0	-3.4	-0.4	-1.0
Compound feed	-2.6	-4.3	-2.1	-2.6
Pig meat	1.3	2.3	1.0	3.9
Poultry meat	3.3	7.7	2.1	3.3
Export				
Pigs (966)[d]	-100.0	-100.0	-100.0	-37.7
Poultry (223)	-37.1	-30.4	-41.1	-37.1
Pig meat (4546)	-7.0	-6.4	-7.2	-22.4
Poultry meat (1406)	-19.6	-20.9	-18.3	-19.6
Import				
Pigs (24)[d]				1.6
Poultry (82)	3.8	-7.6	12.2	3.8
Pig meat (327)	-2.3	-2.8	-2.1	-6.1
Poultry meat (315)	-7.1	-9.3	-6.2	-7.1
Miscellaneous				
Exchange rate (in 1990 guilders/dollar)	0.48	0.55	0.46	0.48
National income (516267)	-0.09	-0.08	-0.09	-0.14
Welfare[b]	-623.9	-717.6	-590.3	-785.1
Rent pig farming[b]	885.7	991.1	853.1	1063.4
Rent poultry farming[b]	353.4	430.1	330.0	353.7

a,b See a,b Table 3.5.

c In the case of low (high) trade elasticities, the absolute values of the trade elasticities are changed from 4.5 to 1.5 (low) and 7.5 (high) for agricultural products (G1-G12) and from 3 to 1.15 (low) and 5 (high) for meat products (G16-G18).

d In the case of the Armington assumption for trade in pigs, net trade in pigs (966 mln guilders) is composed of 990 mln guilders export and 24 mln guilders import.

The results show that, in both cases, there is no trade in pigs. Producer price changes are lower in the case of higher trade elasticities, because domestic poultry prices and prices for pig meat and poultry meat prices are determined, to a larger extent, by world market prices, which are assumed to be constant[9]. Low pig meat prices would result in a lower demand for pigs. However, since there is no trade in pigs and pig production is given, high trade elasticities also result in lower prices for pigs. These lower pig and poultry prices result in a decrease in the income from pig and poultry farming. With low trade elasticities, higher prices for pigs and poultry are translated into higher income. This reflects the fact that as Dutch commodities become more different from foreign commodities, domestic production reduction becomes less harmful for the industries concerned. The results show that with low trade substitution and transformation elasticities, it is even possible that by reducing production, income will rise. The more the domestic and foreign products are differentiated, the higher the rent in agriculture is. The lower welfare shows, however, that low trade elasticities are detrimental for the Netherlands as a whole. The less flexible production structure resulting from low trade substitution and transformation elasticities hampers an efficient allocation of factor inputs and commodities. The previous results are confirmed by the results in column 5 in Table 3.6 where, for the trade in pigs, the Armington assumption is adopted. In this case, an infinitely high trade elasticity is replaced by a lower value. The higher price for pigs results in a higher income from pig farming than in the base simulation. The consequences for the pig meat industry are significant. The higher price for pigs results in lower production and income. For the economy as a whole, the lower flexibility results in lower welfare.

3.6.2 Factor transformation elasticities

Columns 3 and 4 of Table 3.7 show the sensitivity of the results to the magnitude of the factor transformation elasticities determining the degree of factor mobility. It can be concluded that with lower factor mobility than in the base simulation (column 2), fewer

[9] In the case of multi-country models, the consequences of the choice of trade elasticities are more complicated because the monopoly power implicit in national product differentiation is the source of strong terms of trade effects (see Shiells and Reinert, 1993). Terms of trade effects do not occur in single country models in which the small country assumption applies and thus world market prices (for both imports and exports) are assumed to be fixed. In this case, the rest of the world implicitly does not consider the specific country's products as being different from other countries.

factors will leave pig and poultry farming, which results in lower factor prices and higher rents generated. Moreover, due to the fact that more factors stay in the industry, both the quantity and price of aggregate intermediate inputs decrease more than in the base simulation.

Table 3.7 *Effects on the Dutch economy of reducing pig and poultry production at 30 kg/ha phosphate loss, using different factor market elasticities (% change from benchmark)*

Variable[a]	Effects of different simulations (% changes)			
	Base case	Low factor mobility[c]	High factor mobility[c]	Low substitution hired/self employed labour[d]
Quantity production				
Pig farming (7673)	-20.5	-20.5	-20.5	-20.5
Poultry farming (2558)	-20.5	-20.5	-20.5	-20.5
Price production				
Pig farming	2.3	2.4	1.7	2.3
Poultry farming	3.9	4.1	2.8	3.9
Quantity aggregate intermediate input				
Pig farming (1153)	-24.1	-24.7	-22.9	-24.2
Poultry farming (623)	-24.2	-25.2	-22.2	-24.3
Price aggregate intermediate input				
Pig farming	-1.3	-1.8	-0.4	-1.3
Poultry farming	-2.5	-3.1	-1.1	-2.5
Quantity aggregate factor input				
Pig farming (2151)	-9.1	-6.8	-13.5	-9.0
Poultry farming (878)	-12.1	-9.3	-17.0	-11.9
Price aggregate factor input				
Pig farming	-37.2	-42.4	-25.3	-37.5
Poultry farming	-32.7	-40.3	-16.0	-33.2
Income				
Pig farming (2198)	-42.9	-46.3	-35.4	-43.1
Poultry farming (888)	-40.8	-45.8	-30.3	-41.1
Pig meat industry (1169)	-5.4	-5.5	-5.0	-5.4
Poultry meat industry (367)	-17.1	-17.5	-15.9	-17.1
Income including rents				
Pig farming (2198)	-2.6	-0.1	-9.0	-2.5
Poultry farming (888)	-1.0	2.2	-9.3	-0.9
Miscellaneous				
Exchange rate (in 1990 guilders/dollar)	0.48	0.50	0.34	0.48
National income (516267)	-0.09	-0.10	-0.04	-0.09
Welfare[b]	-623.9	-680.0	-345.8	-628.0
Rent pig farming[b]	885.7	1015.8	580.0	893.7
Rent poultry farming[b]	353.4	426.4	186.2	357.4

[a,b] See Table 3.5.

[c] In the case of low (high) factor mobility, the transformation elasticity is changed from -0.5 to -0.3 (low) and -5 (high) for the distribution of labour and from -0.6 to -0.3 (low) and -6 (high) for the distribution of capital.

[d] In the case of low substitutability between self employed and hired labour in agricultural industries, the substitution elasticities are changed from 1.5 to 0.3.

The net effect is that income (including rents) in both pig farming and poultry farming is higher with low factor mobility compared to the base case (in poultry farming income rises). When factor mobility is high, rents will be lower resulting in significantly lower income. It means that, in the long run, rents will disappear due to an adjusting production structure. High factor mobility means more flexibility in the economy, which is beneficial for the economy as a whole, represented by a smaller decrease in welfare. However, it is not necessarily beneficial for an individual industry. Pig and poultry farming profit less from high factor mobility because output prices increase less and feed prices decrease less (in perfectly price-elastic output and factor markets, price changes would be zero), leading to a larger reduction in income, *including* rents. At the same time, with high factor mobility, factor prices are determined, to a larger degree, outside agriculture. This leads to a larger reduction in factor use and a smaller reduction in income *excluding* rents.

In column 5, the effects of a low substitution elasticity between immobile (self employed) and mobile (hired) labour in the agricultural industries are presented. The results are not very sensitive to a change in the substitution elasticity, due to the low share of hired labour in pig, poultry and dairy farming.

3.7 Summary and conclusions

This chapter quantifies the effects on the Dutch economy of different reductions in livestock production necessary to achieve environmentally acceptable phosphate losses using an AGE model. The effects of permitted nitrogen losses are not considered, because this was not yet part of the policy at the time (1996) the study for this chapter was performed. The simulations give a good insight into the effects that stricter mineral policy might cause. The results are, of course, conditional on the model characteristics; e.g., functional forms, specification of agents and commodities, and the static nature of the model, and should be interpreted with care. This is especially the case since AGE models cannot be estimated and tested econometrically.

To permit a better insight into the consequences of mineral policies for the environment, the model would have to include some technical relationships. Mineral surpluses could be generated by means of emission functions and treated by an abatement industry (Nestor and Pasurka, 1995). Moreover, the detrimental effects of a mineral surplus on agricultural production and welfare could be considered. Including minerals in the model would also be useful in showing the inefficiency of reducing livestock production instead of using market-based instruments to reduce the mineral surplus[10].

A decrease in livestock production to achieve a phosphate loss of 30 kg/ha will decrease income (including rents) from pig and poultry farming by 2.6 and 1.0 per cent, respectively. If pig production alone is reduced, the income from pig farming will decrease by 4.8 per cent. This is under the assumption that livestock farmers do not incur manure transportation costs [74 mln guilders in 1992/93; LEI (1994)], pay no levies [36 mln guilders in 1992/93; LEI (1994)] and technological progress is free. However, as this is unrealistic, the effects on income are underestimated. Nevertheless, the fact that the perfect homogeneity assumption in pig trade is used, tends to overestimate the negative effects on income. The lower production in pig and poultry farming affects the production and income of the compound feed, pig and poultry meat industries more seriously than the livestock industries because of the absence of quota rents. The effects on trade are that net exports of livestock and net imports of feedstuffs decrease. Moreover, in all cases, the exchange rate appreciates, which indicates that the trade position of the Netherlands would deteriorate because of the livestock reduction.

Total welfare reductions would be offset by a welfare increase caused by improved environmental quality. However, there are no estimates available of such a welfare improvement.

The results of the model simulations place Dutch manure and phosphate surplus reduction policies in a broader perspective. They also show the important linkages that are present with the rest of the economy. This forms the background to discussions on the advantages and disadvantages of reducing livestock production in Dutch agriculture and on the design of policies in other countries that deal with the same environmental problems.

[10] Of course this would be useful only if emissions are not fully proportional to output in which case the results will be exactly the same. Emissions are related to both inputs and output in Chapters 5 and 6, which deal with restricting eutrophication and nitrogen emissions, respectively.

CHAPTER 4

ENERGY TAXES IN THE NETHERLANDS: WHAT ARE THE DIVIDENDS?[1]

Abstract

In this chapter, the environmental and economic effects of the introduction of a unilateral energy tax in the Netherlands are analysed using an applied general equilibrium (AGE) model. The effects of a small-user energy tax and a general energy tax are compared, while taking into account different tax recycling mechanisms. The AGE model contains a high level of detail with respect to emissions and environmental indicators (indicators measuring the greenhouse effect, acidification, eutrophication and waste accumulation), which is helpful for assessing environmental quality. The results show that the introduction of a small environmental tax reform not only improves the environment but also raises non-environmental welfare, which is due to an improvement in the efficiency of the tax structure.

4.1 Introduction

Like the other signatory countries of the Framework Convention on Climate Change (FCCC), the Netherlands has recognised the importance of its national contribution to the greenhouse effect. To reduce CO_2 emissions (the main greenhouse gas), the Dutch government decided to introduce a unilateral energy tax. A fundamental problem for a small open country is that foreign countries may choose not to use taxes and often pursue a less ambitious environmental policy. Industries which are particularly energy-intensive and which face international competition have to bear a high burden which could also harm the country as a whole (Bovenberg, 1993). Moreover, there is the question whether global emissions of CO_2 will fall because of the energy tax since production of energy intensive commodities may relocate to other countries (emission leakage effect). International reallocation of production is less of a threat if only households and small users are taxed (see Bovenberg, 1993; Hoel, 1996; Böhringer and Rutherford, 1997). The Dutch government implemented their policy by taxing

[1] This chapter is based on Komen and Peerlings (1999).

fossil fuels (except fuels for vehicles) and electricity use by households and 'small' energy users. Moreover, the revenues of the energy tax are used to reduce taxes on labour. In doing so, detrimental effects of the energy tax on energy users are (partly) offset while pre-existing tax distortions in the labour market decrease.

In this chapter, the environmental and economic effects of the introduction of a unilateral energy tax in the Netherlands are analysed using an applied general equilibrium (AGE) model[2]. The effects of a small-user energy tax and a general energy tax are compared, taking into account different tax recycling mechanisms. Although a carbon tax is expected to be more efficient than an energy tax from a welfare perspective, it is not considered in this chapter to keep the analysis of the real tax policy transparent. Special attention is paid to horticulture that is one of the industries that are partly exempted. The chapter contributes to the existing literature on environmental tax reforms in two respects.

Firstly, in the AGE model presented, several emissions related to inputs, production and consumption are explicitly taken into account at a very detailed level. Although in several AGE models emissions are included (Böhringer and Rutherford, 1997, for CO_2 emissions; Larsen, 1997, for NO_x emissions), previous work dealing with multiple emissions at such a detailed level is still scarce. Moreover, emissions are converted into four environmental indicators that measure the greenhouse effect, acidification, eutrophication and waste accumulation. For a good assessment of the environmental effects of an 'environmental tax reform', such environmental detail is necessary because emission factors differ to a large extent among the different agents and emission sources within an economy.

Secondly, this chapter contributes to the notion of the double dividend. According to the 'standard double dividend literature' a revenue-neutral tax reform might: not only (1) improve the environment, but also (2a) reduce the distortionary costs of the tax system, and/or (2b) reduce unemployment (for a clear discussion see Goulder, 1995a; de Mooij, 1999). It is also argued that a second dividend (2a) may not occur when the gains from using pollution tax revenues to substitute for other distortionary tax revenues are offset by the distortionary effects that result from the introduction of the pollution tax itself (see Bovenberg and de Mooij, 1994; Bovenberg and Van der Ploeg, 1994). The results in this chapter show that if only consumers and small energy users are taxed, a double dividend

2 A number of papers have also dealt with the effects of an energy tax using an AGE model, among which: Conrad and Schröder (1991), Böhringer and Rutherford (1997) and Goulder (1995b). Papers dealing with an energy tax in the Netherlands are the Centraal Planbureau (1992 and 1993) and Dellink and Jansen (1995). These papers, however, are not based on the green tax reform of 1996 (e.g., different tax rates and exemptions) while the effects for the environment are not analysed.

occurs. In an exceptional case, a double dividend may even exist when the tax revenues are returned in a lump sum fashion. Both cases are due to inefficiencies in the tax system in the benchmark.

The remainder of this chapter is organised as follows: Section 4.2 sketches the contribution of the different economic agents to the environmental problems in the Netherlands. Section 4.3 deals with specific characteristics of the model used for the analysis in this chapter. Policy simulations are presented in Section 4.4 and some of the results are elucidated in Section 4.5. The responsiveness of the results to some critical assumptions is determined using sensitivity analyses in Section 4.6. Finally, a summary and general conclusions are provided in Section 4.7.

4.2 Emissions and environmental indicators

In this chapter, so-called 'environmental themes' are adopted from the Netherlands' National Environmental Policy Plan (MVROM, 1989). These environmental themes are used as an inventory framework of current environmental issues in the Netherlands. The following environmental themes are considered: greenhouse effect, acidification, eutrophication, and accumulation of waste. To quantify each theme, nine specific emissions are distinguished and, using theme equivalents, converted into four environmental indicators[3].

Table 4.1 *Contribution to greenhouse effect by industries and consumers in the Netherlands (1990)*

	Greenhouse gas excluding CFK's (mln kg CO_2 equivalents[a])				
	CO_2	N_2O	CH_4	Total	Total %
Agriculture[b]	8671	7312	5628	21611	12.1
Agribusiness[b]	4759	0	0	4759	2.7
Other industries[b]	42840	2979	914	46733	26.2
Public utilities[b]	38450	0	793	39243	22.0
Services[b]	24000	1083	88	25171	14.1
Consumption	34570	1896	154	36620	20.5
Waste dumping[c]	0	0	4152	4152	2.3
TOTAL	153290	13270	11730	178290	100.0

a 1 kg N_2O is 270 kg CO_2 equivalent; 1 kg CH_4 is 11 kg CO_2 equivalent.
b To save space, the 37 industries present in the model are aggregated into 5 groups.
c Emissions by waste dumping are related to accumulated waste at rubbish dumps.
Source: CBS-6 (1996) and own calculations.

3 Hence, environmental indicators are a quantification of environmental themes. In the remainder of this thesis, the term 'environmental indicator' will be used as a synonym for 'environmental theme'.

The contribution of the different economic agents in the Netherlands to emissions and environmental indicators in 1990 is summarised in Tables 4.1 to 4.3. The figures presented are aggregated from a larger data set used in the model, which is not shown here to save space. In Table 4.1, the contribution to the greenhouse effect by different sources is shown. Emissions that contribute to the greenhouse effect are carbon dioxide (CO_2), nitrous oxide (N_2O) and methane (CH_4). The emissions are aggregated using kg CO_2 emission equivalents. CO_2 is the most important pollutant in all industries. In agriculture, however, N_2O and CH_4 are also important greenhouse gases.

Table 4.2 *Contribution to acidification by industries and consumers in the Netherlands (1990)*

	Acidification (mln acid equivalents[a])				
	NO_x	SO_2	NH_3	Total	Total %
Agriculture	395	63	13857	14316	42.5
Agribusiness	307	63	0	370	1.1
Other industries	2876	3784	178	6838	20.3
Public utilities	1668	1482	0	3150	9.4
Services	3468	820	0	4288	12.7
Consumption	3885	158	654	4697	14.0
TOTAL	12600	6370	14690	33660	100.0

[a] Quantities of acidifying compounds are expressed in molarity: 1 acid equivalent is equal to 1 mole H^+.
1 kg NO_x is 0.22 acid equivalent; 1kg SO_2 is 0.31 acid equivalent; 1 kg NH_3 is 0.59 acid equivalent.
Source: CBS-6 (1996) and own calculations.

Table 4.2 shows the acidification sources. Emissions that contribute to acidification are nitrogen oxides (NO_x), sulphur dioxide (SO_2) and ammonia (NH_3). The different emissions are aggregated using acid equivalents. NH_3, mainly emitted in agriculture, is the most important pollutant.

Table 4.3 *Contribution to eutrophication and waste by industries and consumers in the Netherlands (1990)*

	Eutrophication (mln kg N equivalents[a])				Waste (mln kg)	
	N	P	Total	Total %	Waste	Total %
Agriculture	1197	1324	2521	73.6	731	3.1
Agribusiness	29	90	119	3.5	1647	7.0
Other industries	51	80	131	3.8	10262	43.6
Public utilities	23	0	23	0.7	610	2.6
Services	105	261	366	10.7	3850	16.4
Consumption	126	140	266	7.8	6440	27.4
TOTAL	1531	1896	3427	100.0	23540	100.0

[a] 1 kg P is 10 kg N equivalents.
Source: CBS-6 (1996) and own calculations.

Table 4.3 shows the contribution of different sources to eutrophication and waste accumulation. Nitrogen (N) and phosphate (P) are aggregated using kg nitrogen equivalents. Clearly, agriculture with its high livestock production is the most important contributor to eutrophication in the Netherlands.

An advantage of environmental indicators is that they summarise different types of emissions. There are, however, also at least three drawbacks when environmental indicators are used in the way described. First, not all harmful emissions are considered (e.g., pesticides, dioxin, heavy metals, etc.). Second, the environmental indicators do not reflect the current quality of the environment. Environmental indicators are considered as being flows while some emissions are only harmful after reaching a certain stock (e.g., the accumulation of phosphate into the soil). Moreover, there exist also international flows of emissions that are not considered in this chapter. Third, although different emissions can be aggregated into single environmental indicators, the same is not true for the indicators themselves. From a policy perspective, it still seems a matter of subjective choice, which weight to attach to each environmental indicator.

Although the overall environmental quality may be determined in a higher spatial and time dimension, environmental indicators are useful to evaluate the environmental effects of environmental policies.

4.3 Model characteristics

The model applied in this chapter is calibrated on the 1990 data set. This section deals with the specific adjustments of the model described in Chapter 2 that are used for the simulations in this chapter. Moreover, some features of the model that are especially relevant in light of the analysis in this chapter are discussed.

4.3.1 Energy taxes and tax revenue recycling

In this chapter, a reduction in domestic energy use is achieved by means of an energy tax. The energy tax is levied on certain commodities for domestic industries and consumers (see Section 4.4 for a description of the model simulations). Hence, the relevant price equations in the model for intermediate energy inputs (I.36) and private household demand (I.37) need to be replaced by (4.1) and (4.2), respectively, to take the energy tax rate, t^{en}, into account:

$$WIN_{b,g} = (1+t_{b,g}^{en}).WDU_g \qquad \forall b \in B, \forall g \in S_{en} \qquad (4.1)$$

$$WDU_g^{con} = (1+m_g^{con}+t_g^{en}).WDU_g \qquad \forall g \in S_{en} \qquad (4.2)$$

Energy tax revenues TX^{en} is given by equation (4.3):

$$TX^{en} = \sum_{g \in S_{en}} t_g^{en}.WDU_g.X_g^{con} + \sum_{b \in B}\sum_{g \in S_{en}} t_{b,g}^{en}.WDU_g.IN_{b,g} \qquad (4.3)$$

In this chapter, the revenues of the energy tax are used to reduce taxes on labour. Hence, the tax rate in the price equation of labour (I.45) is adjusted for an endogenous tax recycling rate, r^{labtot}:

$$WTPR_1 = WTPR_1^{excl}.(1+t^{labtot}-r^{labtot}) \qquad (4.3)$$

Simulations are based on a revenue-neutral tax reform in the sense that welfare derived by government consumption is held fixed in order to derive a transparent welfare analysis. Since the tax reform might also induce changes in revenues of other taxes or changes in prices of government consumption, an endogenous tax transfer TX^{trans} is added to the government budget equation (I.61) to achieve such a zero change in government welfare:

$$I^{gov} = TX + DEF + \overline{TR^{gov}}.ER - TX^{trans} \qquad (4.4)$$

The energy tax revenues corrected for the tax transfer equal the total reduction in taxes on labour, which is represented by equation (4.5):

$$TX^{en} + TX^{trans} = r^{labtot}.WTPR_l^{excl}.TPR_l \qquad (4.5)$$

If, for example, the tax reform induces lower prices for commodities consumed by the government, TX^{trans} will be positive. At lower prices, the government budget can be reduced to achieve an equal welfare and more taxes can be used to reduce taxes on labour.

4.3.2 Caveats

The model as applied for the purpose in this chapter, has some caveats that are elucidated before the analysis takes place. First, since capital supply is assumed fixed, a tax on capital will not entail an excess burden. Redistribution of the tax burden from labour towards capital is therefore always welfare improving. The introduction of an energy tax described above could generate such a redistribution since energy tax revenues are used to reduce taxes on labour. Given the assumption of a fixed capital supply, however, it should be kept in mind that the results in this chapter are only valid in the short term. Second, it should be recognised that the small open economy model fails to account for trade-related impacts on global emissions (e.g., carbon leakage effect). Third, because there is only one representative household in the model, equity issues cannot be dealt with, which is relevant when changes in the tax system are considered. Fourth, all markets are assumed perfect. An increase in employment due to changes in the tax scheme, however, might lead to a stronger bargaining power with a consequent stronger rise in real wages. Introducing such a bargaining model will certainly influence the effects of an environmental tax reform (Welsch, 1996). Moreover, although energy suppliers in the Netherlands are privatised they are still under strong government regulation and some evidence suggests that they behave under imperfect competition. If this were the case, it would influence the calculated environmental and economic effects of an energy tax[4]. Finally, environmental quality (e.g., expressed by environmental indicators) is not an argument in the utility function of the representative household. This makes it impossible to determine 'true' welfare effects (including environmental quality). Environmental quality is not included in the utility function because the implicit weights necessary for incorporation of indicators are lacking due to insufficient empirical information.

4.4 Policy simulations

The small-user energy tax in the Netherlands, introduced in 1996, is summarised in Table 4.4. It shows that the first 800 m^3 gas and 800 kWh electricity for each user are exempted from

[4] A unit tax on output entails a lower reduction of output in case of a monopoly than under perfect competition since the relevant response function of a monopoly (marginal revenue function) is steeper than the relevant function under perfect competition (demand function). In case of oligopolistic behaviour, matters become more complicated since then strategic behaviour (e.g., price setting) might be involved. See also Baumol and Oates (1988) for a discussion on Pigouvian taxes under imperfect competition.

taxation. Moreover, usage above 170,000 m^3 gas and 50,000 kWh electricity is also excluded.

Table 4.4 *The Dutch small-user energy tax*

Energy user	Gas	Electricity
Households	> 800 m^3	> 800 kWh
Firms (small users)	800-170 000 m^3	800-50 000 kWh
Firms (large users)	800-170 000 m^3	no tax
Horticulture	no tax	800-50 000 kWh

Source: Energie Beheer Nederland, 1995.

The different thresholds imply that the relevant price of electricity and gas for a small and large user includes respectively excludes the tax. Although in horticulture small users are dominant, firms are exempted from the energy tax on gas. The government considers taxing this energy intensive industry as a too large threat for its international competitiveness. In addition to gas, also other fuels for heating (excluding coal) are taxed. Fuels for vehicles are not included.

In this chapter, two simulations are dealt with. The first simulation considers the small-user energy tax, which is implemented in the Netherlands in 1996. In this simulation the use of distributed gas, other fuels for heating and electricity is taxed for small users[5]. In the second simulation (general taxation), the tax base is broadened to all industries and exemptions are not considered. In this case, also coal and natural gas (only used by large users) are taxed. Public utilities are still exempted from taxation in order to avoid double taxing. To be able to compare the two simulations, tax rates will be adjusted in the general tax simulation such that the same CO_2 reduction will be achieved as in the small-user tax case.

In reality, the introduction of the small-user energy tax will take place in three steps. In the simulations in this chapter ad valorem tax rates are applied which are approximately the final tax rates that will be used in 1998: 25 per cent for gas, 15 per cent for electricity, 25 per

[5] The different thresholds imply that the relevant price of energy for small and large users includes respectively excludes the energy tax. Consumers and industries where small users are dominant have to pay the tax. Consumers and small users do not have to pay the tax over the first 800 m^3 gas and 800 kWh electricity use. This is modelled by taxing total use and a partial lump sum tax return. For those industries where large users are dominant (mainly food processing, chemical and metal industries) it is assumed that the relevant prices exclude the tax. However, these industries have to pay the energy tax over the range of 800-170,000 m^3 taxable gas use. This is modelled by means of a lump sum transfer from the industries to the government. Notice that this policy measure gives no incentive for large users to reduce gas use.

cent for coal and 20 per cent for other fuels for heating. In the simulation of the general tax, tax rates were adjusted to 46.6 per cent of the small-user energy tax rates.

In both simulations, energy tax revenues are used to reduce the adverse effects of the tax by reducing pre-existing distortionary taxes on labour[6]. Alternative recycling mechanisms will be considered in the sensitivity analysis.

4.5 Results

Effects on industries and consumers

The 'economic' effects of the different simulations on some selected industries and consumers are summarised in Table 4.5. The table shows that the small-user energy tax results in higher prices of distributed gas (20.3 per cent), other fuels (16.6 per cent) and electricity (10.0 per cent) for small users and lower prices for large users (-3.8, -2.8 and -4.4 per cent, respectively). These lower prices result from the fact that with perfect competition energy supply is price elastic and hence prices excluding taxes are lower at a smaller supply. Consumers use less distributed gas (5.2 per cent), other fuels for heating (4.0 per cent) and electricity (2.6 per cent). Being exempted from an energy tax on gas, large users profit from the lower price of energy. The fertiliser industry, for example, uses 1.7 per cent more natural gas, increasing production and income by 1.2 and 1.9 per cent, respectively. Horticulture under glass also profits, being exempted from the tax on distributed gas. The use of distributed gas increases by 1.1 per cent, electricity use decreases by 0.9 per cent (horticulture under glass is not exempted from the tax on electricity), production increases by 0.2 per cent and income also increases by 0.2 per cent. Horticulture under glass also profits from the lower price of labour (tax revenues are used to lower taxes on labour) which causes an increase in labour demand (0.2 per cent).

The effects on the other agricultural industries are negative. Income and production in dairy farming, pig farming, poultry farming, arable farming and other horticulture fall (see Table 4.6). The higher costs for distributed gas, other fuels for heating and electricity and the decrease in the exchange rate (appreciation of the guilder) have a negative effect on both production and income. Because these agricultural industries do not use much labour (other than self employed labour), they hardly profit from lower taxes on labour.

6 In the model (see Chapter 2), labour taxes paid by employers (different in each industry) are distinguished from labour taxes paid by employees (single tax rate). To realise an equal distribution of the taxes over all industries, revenues are recycled by reducing the labour tax rate for employees.

Table 4.5 *Effects on income, production, employment, energy use and prices for selected industries and consumers of energy taxes (% change from benchmark)*

Variable[a]	Small-user energy tax	General energy tax
Coal		
Use by electricity supply (890)	-4.8	-3.2
Price including tax	-	11.9
Price excluding tax	-0.1	0.2
Natural gas		
Use by electricity supply (1539)	-4.5	-2.9
Use by fertiliser industry (606)	1.7	-15.2
Use by gas distribution (5933)	-6.2	-3.7
Price including tax	-	20.6
Price excluding tax	-2.2	-2.1
Distributed gas		
Consumption (4577)	-5.2	-2.2
Horticulture under glass (766)	1.1	-3.6
Price including tax	20.3	8.3
Price excluding tax	-3.8	-3.0
Other fuels for heating		
Consumption (38)	-4.0	-1.9
Price including tax	16.6	7.7
Price excluding tax	-2.8	-1.5
Electricity		
Consumption (2747)	-2.6	-0.9
Horticulture under glass(101)	-0.9	-3.0
Price including tax	10.0	3.7
Price excluding tax	-4.4	-3.1
Fertiliser		
Use by dairy farming (337)	-0.1	-0.3
Use by arable farming (188)	-0.1	-0.4
Price domestic use	-0.8	6.6
Production		
Electricity supply (11283)	-4.3	-2.8
Gas distribution (8490)	-6.0	-3.6
Petroleum industry (21047)	-2.1	-1.5
Fertiliser industry (2344)	1.2	-11.0
Horticulture under glass (7378)	0.2	-0.7
Labour demand		
Electricity supply (1808)	-3.7	-2.4
Gas distribution (687)	-5.0	-3.0
Petroleum industry (814)	-0.7	-0.3
Fertiliser industry (343)	0.7	-6.6
Horticulture under glass[b] (1168)	0.2	-0.3
Income		
Electricity supply (5309)	-10.4	-7.1
Gas distribution (1820)	-13.8	-8.8
Petroleum industry (3067)	-2.3	-1.3
Fertiliser industry (676)	1.9	-18.3
Horticulture under glass (4685)	0.2	-1.3

[a] Base year quantities, in mln 1990 guilders, between parentheses.

Table 4.6 *Effects on production and income in agricultural industries of energy taxes (% change from benchmark)*

Variable[a]	Small-user energy tax	General energy tax
Production		
Dairy farming (12734)	-0.1	-0.2
Pig farming (7669)	-0.3	-0.0
Poultry farming (2557)	-0.2	0.1
Arable farming (3556)	-0.1	-0.2
Horticulture under glass (7378)	0.2	-0.7
Other horticulture (4634)	-0.3	0.1
Income		
Dairy farming (5554)	-0.3	-0.2
Pig farming (2155)	-0.9	0.0
Poultry farming (878)	-0.5	0.2
Arable farming (1522)	-0.3	-0.3
Horticulture under glass (4685)	0.2	-1.3
Other horticulture (2965)	-0.7	0.4

[a] See Table 4.5.

Table 4.7 shows the effects at the national level. Total domestic use of natural gas, other fuels and electricity decrease by 4.1, 7.5 and 4.6 per cent, respectively. The reduction of labour costs, by means of recycling 2432 million guilders (1990)[7], results in 0.10 per cent more employment and a redistribution of welfare from leisure towards private consumption and savings. The changing tax base decreases the excess burden due to existing tax distortions (second best welfare improvements) which results in a higher total national welfare of 0.06 per cent (see also Section 4.6). When the tax base is broadened to all industries, while the same CO_2 reduction is achieved, total domestic use of natural gas decreases more (5.4 per cent) than in the small-user tax case. The reduction of all other energy sources is less than in the small-user tax case. Apparently, large energy users use relatively more natural gas than small energy users. For example, the fertiliser industry, not being exempted, now uses 15.2 per cent less natural gas and produces 11.0 per cent less. Due to the very energy intensive production, income of the fertiliser industry decreases by 18.3 per cent. Production and income in horticulture under glass decrease by 0.7 and 1.3 per cent, respectively, while electricity and gas use decrease by 3.0 and 3.6 per cent, respectively. These input price increases are not compensated by the lower labour costs. Employment in horticulture under glass decreases by 0.3 per cent. Although total employment increases by 0.15 per cent and more pre-existing tax distortions on labour are removed by recycling 3014 million guilders

[7] The amount of tax that is recycled is not exactly equal to the energy tax revenues, because the simulations are based on a government welfare-neutral tax reform, which is achieved by a lump sum transfer between energy tax revenues and non-environmental tax revenues.

(1990), welfare decreases by 0.02 per cent. The exchange rate increases by 0.25 per cent, indicating that in the case of the general tax, international competitiveness of the large energy-using industries has deteriorated. The negative effects on the other agricultural industries due to the energy tax are smaller than in the case of a small energy tax, because the same reduction in greenhouse gases is now achieved by more industries (lower energy tax). Moreover, the increase in the exchange rate in the case of a general energy tax, (depreciation of the guilder) has a positive effect on income. Opposite to this is the negative effect of a higher price for the input of fertiliser (dairy farming and arable farming).

Table 4.7 *Effects on domestic energy intensive commodities, welfare and employment at the national level of energy taxes (% change from benchmark)*

Variable[a]	Small-user energy tax	General energy tax
Total domestic use		
Coal (1531)	-3.0	-2.3
Natural gas (10031)	-4.1	-5.4
Distributed gas (7905)	-6.0	-3.6
Other fuels for heating (975)	-7.5	-5.1
Electricity (10004)	-4.6	-3.0
Fertiliser (750)	0.2	-2.3
Welfare[b]		
Welfare private consumption (280134)	0.05	0.06
Welfare public government (74795)	0	0
Welfare leisure (40035)	-0.39	-0.59
Welfare savings (105640)	0.33	-0.06
Total welfare (500604)	0.06	-0.02
Miscellaneous		
Exchange rate[c]	-0.13	0.25
Total employment (239939)	0.10	0.15
General wage rate (excl. tax)	1.0	1.0
Energy tax paid by industries[d]	1065	1382
Energy tax paid on consumption[d]	829	694
Tax recycling[d]	2432	3014

[a] See Table 4.5.
[b] Welfare expressed in million guilders (1990).
[c] Exchange rate expressed as guilder per dollar (1990).
[d] Tax revenues in million guilders (1990).

Environmental effects

In Table 4.8, the effects of the small-user energy tax and the general energy tax on CO_2 emissions are summarised. In the case of a small-user energy tax, total CO_2 emissions decrease by 3.5 per cent. A domestic carbon leakage effect occurs in agriculture (0.2 per cent) and agribusiness (1.5 per cent), where the increase of CO_2 emissions by large users dominate the decrease of CO_2 emissions by small users.

Table 4.8 *Effects on CO_2 emission of energy taxes (% change from benchmark)*

CO_2 emission[a]	Small-user energy tax	General energy tax
Agriculture (8671)	0.2	-3.0
Agribusiness (4759)	1.5	-5.4
Other industries (42840)	-2.7	-6.0
Public utilities (38450)	-4.7	-3.1
Services (24000)	-6.3	-2.8
Consumption (34570)	-2.9	-1.3
TOTAL (153290)	-3.5	-3.5

[a] Base year CO_2 emissions, in mln kg, between parentheses.

When the tax base is broadened to all industries, CO_2 emissions in agriculture, agribusiness and other industries are lower than in the small-user tax case, since large users are not exempted (e.g., fertiliser industry, horticulture under glass). Emissions by public utilities, services and consumers are higher in the general tax case since tax rates are lower in order to achieve the same CO_2 reduction as in the small-user tax case.

Table 4.9 *Effects on environmental indicators by different industries and consumers of energy taxes (% change from benchmark)*

Environmental indicator	Greenhouse effect		Acidification		Eutrophication		Waste accumulation	
	Small	General	Small	General	Small	General	Small	General
Agriculture	0.0	-1.3	-0.2	-0.1	-0.2	-0.1	-0.1	-0.2
Agribusiness	1.5	-5.4	0.6	-4.3	0.3	-0.5	0.1	-0.1
Other industries	-2.5	-5.6	-4.4	-4.7	-0.3	-4.0	0.2	-0.5
Public utilities	-4.7	-3.1	-4.7	-3.1	-4.7	-3.1	-4.3	-2.8
Services	-6.0	-2.7	-1.1	-0.5	-0.2	-0.1	0.0	0.0
Consumption	-2.7	-1.2	-0.5	-0.3	0.1	-0.1	0.0	0.1
Waste dumping	0.0	0.0	-	-	-	-	-	-
TOTAL	-3.1	-3.1	-1.6	-1.5	-0.2	-0.3	0.0	-0.3

In Table 4.9, the effects of the small-user energy tax and the general energy tax on environmental indicators are summarised (see Appendix X for quantification at emission level and Appendix XI for the effects on emissions in agriculture). In the case of the small-user energy tax, the greenhouse effect from emissions in the Netherlands decreases by 3.1 per cent. The effects of an energy tax on the other environmental indicators are much smaller, which is due to a less distinct relation to energy use. For example, although the emissions of

NO_x and SO_2 decrease, the relative small decrease of NH_3 in agriculture causes a reduction in acidification in the small-user tax case of only 1.6 per cent. In the general tax case, acidification reduction is even smaller (1.5 per cent) because the assumed CO_2 reduction is now achieved by relatively reducing more natural gas use. The SO_2/CO_2 emission-ratio of natural gas is lower than the other energy sources.

4.6 Sensitivity analysis

This section contains a sensitivity analysis with respect to assumptions in the model that are relevant for this chapter: the tax recycling scheme and labour market parameters.

4.6.1 Tax recycling scheme

The previous results in this chapter show that in the case of a small-user energy tax, both economic welfare and the environment improve. Hence, a double dividend is achieved. Some "...literature on the double dividend suggests, however, that environmental taxes typically exacerbate, rather than alleviate, pre-existing tax distortions" (de Mooij and Bovenberg, 1995, p.1). In this literature, two effects are distinguished. A *tax interaction effect* occurs due to the interaction of the new environmental tax and pre-existing tax distortions. When there is only one factor of production (e.g., labour), this tax interaction effect is typically welfare deteriorating because it exacerbates existing tax distortions. A positive *tax recycling effect* occurs because environmental tax revenues can be used to reduce pre-existing tax distortions. The 'general conclusion' is that the tax interaction effect is greater than the tax recycling effect and hence a double dividend is not achieved. More recent literature shows, however, that an increase in welfare is much more likely when more than one factor of production is assumed (see de Mooij and Bovenberg, 1995). In this case, the initial situation allows for an inefficient distribution of the tax burden over factors. An environmental tax can alleviate (exacerbate) this inefficiency if the tax burden is redistributed from overtaxed (undertaxed) factors towards undertaxed (overtaxed) factors. Depending on the inefficiency of the initial tax system, it is possible that the sum of the tax interaction effect and tax recycling effect is positive and hence an environmental tax reform entails a welfare increase. Since there are two factors of production in this chapter, fixed capital (hence undertaxed) and elastically supplied labour (hence overtaxed), the latter case applies. Given these assumptions, the effects of different tax recycling mechanisms and different tax rates are analysed.

Tax recycling mechanisms

Table 4.10 contains results of a sensitivity analysis with respect to different tax recycling mechanisms. In the table, the total effect of the environmental tax reform is separated in a tax interaction effect and a tax recycling effect. To determine the tax interaction effect of the environmental tax reform, tax revenues are lump sum recycled to private income. The tax interaction effect is positive (132.7 mln guilders (1990)) in the case of a small-user energy tax which implies that lump sum recycling of tax revenues redistributes the tax burden such that total distortions decrease. For the small-user tax case, four alternative recycling mechanisms are considered: reducing labour tax, capital tax, income tax and consumption tax. Since labour is the only elastically supplied factor, recycling tax revenues by reducing taxes on labour generates the largest positive welfare effect (189.9 mln guilders (1990)). Recycling revenues by reducing taxes on capital generates the same result as lump sum recycling since capital supply is assumed fixed. Recycling revenues by reducing income or consumption taxes generates intermediate results.

When the tax base is broadened to all energy users, it turns out that the tax interaction effect is negative (-352.7 mln guilders (1990)), which is partly due to a deterioration of international competitiveness of the large energy-using industries. Clearly, this negative effect is not offset by the positive tax recycling effect (234.4 mln), when revenues are recycled towards labour.

Table 4.10 *Effects on welfare of energy taxes, using different tax revenues recycling schemes (in mln 1990 guilders)*

	Small-user energy tax				General energy tax
Recycling to:	Labour	Capital	Income	Consumption	Labour
Tax interaction effect	132.7	132.7	132.7	132.7	-352.7
Tax recycling effect	189.9	0.0	72.6	93.3	234.4
Total effect	322.6	132.7	205.3	226.0	-118.3

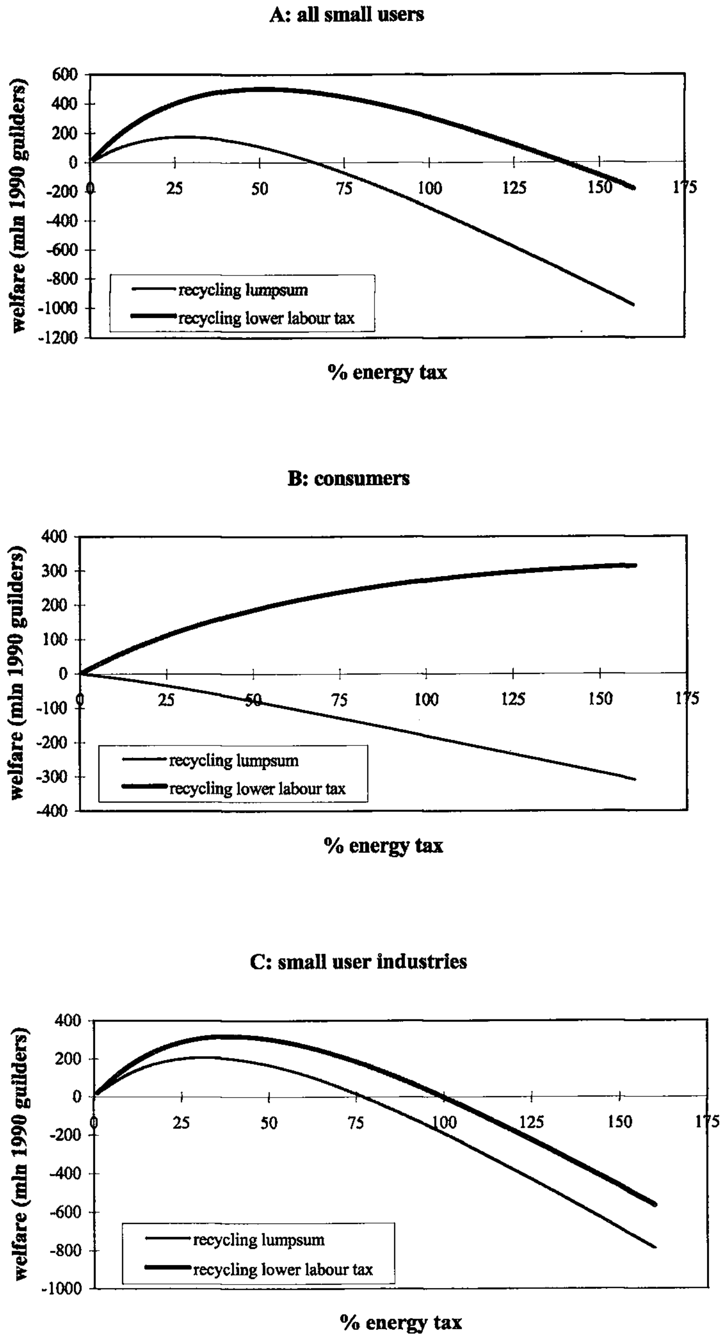

Figure 4.1 *Welfare effects of a small-user energy tax*

Tax rates

In the previous analysis, it was concluded that in the case of a small-user energy tax, the welfare effect of lump sum tax recycling (tax interaction effect) is positive. Further analysis for the small-user tax shows that this is only valid at low tax rates (see Figure 4.1A). As soon as tax rates are as high as 67 per cent, lump sum recycling generates a negative welfare effect. When tax revenues are recycled towards labour, the welfare effect becomes negative at a rate higher than 140 per cent.

If only consumers are considered (Figure 4.1B), lump sum tax recycling always generates a negative welfare effect[8]. When the energy tax revenues are recycled towards labour, however, the redistribution of the tax burden from the overtaxed factor (labour) towards the undertaxed factor (capital) is large enough to entail a positive welfare effect.

If only small energy-using industries are considered (Figure 4.1C), an energy tax entails a positive welfare effect even when the tax revenues are recycled lump sum. This implies that the introduction of the energy tax itself already generates a redistribution of the tax burden large enough to offset distortionary effects of the energy tax itself[9]. When tax revenues are recycled towards labour, the positive welfare effect is even greater since existing labour tax distortions are reduced.

Figure 4.2 shows the welfare loss at different rates of CO_2 reduction for the small-user energy tax and the general energy tax, when tax revenues are recycled towards labour. The figure repeats the results achieved above that the small-user energy tax entails a welfare gain at low CO_2 reduction levels, which is due to households as well as small industries. At higher CO_2 reduction rates, small industries cause a welfare loss. Ultimately, the welfare loss caused by small industries offsets the welfare gain by households. An even larger CO_2 reduction, in combination with a small tax base, causes the welfare loss to increase rapidly.

Since large energy users already entail a welfare loss at low tax rates, a general user tax will perform worse than a small-user tax at low CO_2 reductions. However, it turns out that at higher tax rates, necessary to entail high CO_2 reductions, the welfare loss of a general energy tax is lower than in the case of a small energy tax, which is due to the broader tax base of the former.

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8 Taxes on consumption reduce the real wage rate and hence directly affect the labour-leisure choice.

9 It should be noted that this is not a general result. Detailed analysis showed that the welfare effect of lump sum tax recycling is negative for most industries (the results are available upon request). The positive welfare effect of lump sum tax recycling at low tax rates is caused by a few industries (B34-B37). Taxing these industries is more efficient since the commodities produced by these industries are mainly non-tradeables of which domestic demand is inelastic.

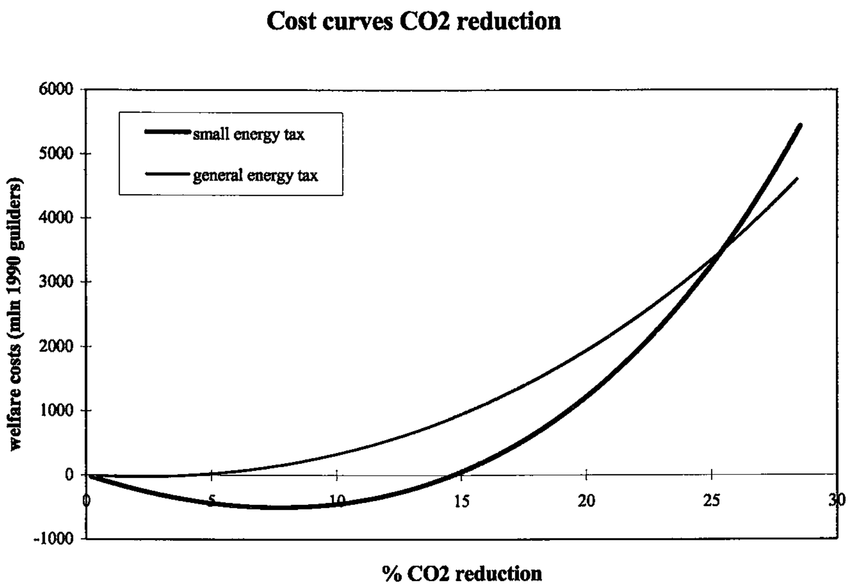

Figure 4.2 *Welfare effects of small-user energy tax and general energy tax (revenues recycled towards labour)*

Figure 4.2 also shows that a 25 per cent reduction of CO_2 in both scenarios leads to a welfare loss of only 0.7 per cent (approximately 3300 mln guilders (1990)). In other studies, also relative low welfare losses are reported at such large CO_2 reductions. Zhang and Folmer (1998), for example, report a welfare loss of 1.1 per cent when CO_2 emission is reduced by 20 per cent. In addition, Whalley and Wigle (1991) report a welfare reduction of 2 per cent when CO_2 emissions are reduced by 50 per cent. In these papers, however, tax revenues were not used to reduce other pre-existing tax distortions.

4.6.2 Labour market parameters

Most simulations in this chapter are related to reducing tax distortions in the labour market. Therefore, it is important to determine the responsiveness of the model results to some of the parameters describing the labour market. This section considers different uncompensated labour supply elasticities, labour mobility and initial unemployment rates.

Uncompensated labour supply elasticity

The base simulations are based on an uncompensated labour supply elasticity of 0.12[10]. Columns 3 and 4 of Table 4.11 show the results for a lower (0.04) and higher (0.20) uncompensated labour supply elasticity. The results show that the model is robust with respect to the magnitude of the uncompensated labour supply elasticity. Although total employment, the wage rate and the welfare distribution change slightly, the other results are almost identical to the base case situation.

Table 4.11 *Effects on Dutch economy of a small-user tax, using different uncompensated labour supply elasticities (% change from benchmark)*

Variable[a]	Base case	Low supply elasticity[b]	High supply elasticity[b]
Employment			
Total employment (239939)	0.10	0.06	0.13
General wage rate (excl. tax)	1.02	1.02	1.00
Welfare			
Welfare private consumption (280134)	0.05	0.02	0.07
Welfare public consumption (74795)	0	0	0
Welfare leisure (40035)	-0.39	-0.26	-0.53
Welfare savings (105640)	0.33	0.31	0.36
Total welfare (500604)	0.06	0.06	0.07
Taxes			
Energy tax paid by industries	1065	1065	1065
Energy tax paid on consumption	829	828	829
Tax recycling	2432	2375	2490
Environment			
Greenhouse effect	-3.1	-3.1	-3.1
Acidification	-1.6	-1.7	-1.6
Eutrophication	-0.2	-0.2	-0.2
Waste accumulation	0.0	0.0	0.0

a See Table 4.7 for units.
b In the case of low (high) uncompensated labour supply elasticity, the elasticity is changed from 0.12 to 0.04 (low) and 0.20 (high).

10 The value of 0.12 is chosen rather arbitrary from van Soest (1995) who finds a 80 per cent confidence interval for the average male's and female's own wage elasticities of expected hours worked, of [-0.005, 0.048] and [0.269, 0.362], respectively.

Labour mobility

In the base simulations, a labour transformation elasticity of -0.5 is used to determine the degree of labour mobility between industries. Columns 3 and 4 of Table 4.12 show the results for a (in absolute terms) lower (-0.25) and higher (-0.75) transformation elasticity. Clearly with a higher (lower) elasticity, labour is able to move easier (more difficult) between industries and hence absolute changes in employment in industries are greater (smaller). Again the other results (not shown in the table) hardly change.

Table 4.12 *Effects on Dutch economy of small-user energy tax, using different labour transformation elasticities (% change from benchmark)*

Variable[a]	Base case	Low labour mobility[b]	High labour mobility[b]
Employment			
Labour electricity supply (1808)	-3.7	-2.8	-4.2
Labour gas distribution (687)	-5.0	-4.0	-5.5
Labour fertiliser industry (343)	0.7	0.5	0.9
Total employment (239939)	0.10	0.09	0.10
General wage rate (excl. tax)	1.02	0.97	1.04
Welfare			
Welfare private consumption (280134)	0.05	0.04	0.05
Welfare public consumption (74795)	0	0	0
Welfare leisure (40035)	-0.39	-0.36	-0.41
Welfare savings (105640)	0.33	0.32	0.34
Total welfare (500604)	0.06	0.06	0.07

a See Table 4.7 for units.
b In the case of low (high) labour mobility, the transformation elasticity is changed from -0.5 to -0.25 (low) and -0.75 (high).

Unemployment rate

In the base simulations, an initial unemployment rate of 20 per cent (including voluntary unemployment) is used to calibrate leisure and mobile labour. Columns 3 and 4 of Table 4.13 show the results for a lower (10 per cent) and higher (30 per cent) initial unemployment rate. Again, the results are rather robust. At a lower initial unemployment rate, the positive welfare effects of reducing labour taxes are lower than in the case of a high initial unemployment rate. Clearly, with low unemployment, the existing disturbance in the labour market is lower and hence reducing labour taxes will generate a smaller welfare improvement. Other results of the model hardly change.

Table 4.13 *Effects on Dutch economy of a small-user energy tax, using different unemployment rates in the benchmark (% change from benchmark)*

Variable[a]	Base case	Low unemployment[b]	High unemployment[b]
Employment			
Labour electricity supply (1808)	-3.7	-3.7	-3.7
Labour gas distribution (687)	-5.0	-5.0	-5.0
Labour fertiliser industry (343)	0.7	0.7	0.7
Total employment (239939)	0.10	0.07	0.13
General wage rate (excl. tax)	1.02	1.02	1.01
Welfare			
Welfare private consumption (280134)	0.05	0.03	0.06
Welfare public consumption (74795)	0	0	0
Welfare leisure (40035)	-0.39	-0.65	-0.30
Welfare savings (105640)	0.33	0.30	0.37
Total welfare (500604)	0.06	0.06	0.07

a See Table 4.7 for units.
b In the case of low (high) unemployment, the unemployment rate is changed from 20% to 10% (low) and 30% (high).

4.7 Summary and conclusions

In this chapter, the environmental and economic effects of the introduction of a unilateral energy tax are analysed. The simulations in this chapter show that the small-user energy tax causes a CO_2 reduction of 3.5 per cent while total emissions of greenhouse gases are reduced by 3.1 per cent. This result is less than the target of 3-5 per cent reduction in 1989-1990 CO_2 levels by 2000, established by the Dutch government, because economic growth is not considered in the model. The results are hardly comparable with other studies focusing on the effects of an energy tax on the Dutch economy, which is due to different modelling assumptions and policy simulations[11].

By recycling revenues of the small-user energy tax, employment increases by 0.10 per cent and existing tax distortions decrease (second best welfare improvements), resulting in a higher national welfare of 0.06 per cent. When the tax base is broadened to all energy users and exemptions are ignored, welfare decreases by 0.02 per cent and the exchange rate increases by 0.25 per cent. This illustrates that in the case of the general energy tax, internati-onal competitiveness of the large energy-using industries deteriorates.

[11] A comparison with other studies for the Netherlands is difficult for reasons mentioned in footnote 2.

The effects of a small-user and general energy tax on acidification, eutrophication and waste is smaller than for greenhouse gas emissions, which is due to the less distinct relation of these indicators with energy sources. The distribution of the environmental effects among the different industries and consumption, however, is rather different between both tax regimes.

Sensitivity analyses of the results show that the positive welfare effects of a small-user energy tax only apply at low tax rates. At higher tax rates, the negative distortionary effects of the introduction of a small-user energy tax dominate the positive effect of redistributing existing distortions from labour to capital. At a certain CO_2 reduction, welfare costs of a small-user energy tax even become higher than welfare costs of a general energy tax, which is due to a broader tax base of the general tax.

It thus seems that, under the restrictions of the model used, a second dividend can be achieved by the introduction of a small-user energy tax. At low tax rates, a welfare improvement is even possible when the revenues of a small-user energy tax are recycled in a lump sum fashion. These typical second-best results occur due to an inefficient initial distribution of the tax burden. From a policy perspective the question remains, however, whether introducing an energy tax is the appropriate tool to reduce distortions caused by other taxes.

CHAPTER 5

MULTIPLE ENVIRONMENTAL POLICY GOALS: ECONOMIC EFFECTS AND INTERACTION OF POLICIES

Abstract
This chapter analyses the environmental and economic effects of restricting the environmental indicators that measure the greenhouse effect, acidification, eutrophication and waste accumulation, using a system of emission permits in an applied general equilibrium model for the Netherlands. Attention is paid to the different effects of restricting single environmental indicators, the interaction effects of restricting different environmental indicators simultaneously and the extent of tradeability of emission permits. In doing so, the main causal relationships linking the economy and the environment are quantified and shadow prices of restrictions on different environmental indicators can be determined.

5.1 Introduction

Like in most industrialised countries, the concern for improving environmental quality has taken a firm place on the policy agenda in the Netherlands. The Dutch government has developed policy targets, specified in terms of environmental indicators that measure phenomena like the greenhouse effect, acidification, eutrophication, and waste accumulation. Typically, each policy target entails a reduction in emissions that cause the environmental problem measured by the indicator. For the government, in aiming at these targets, it is important to understand the nature of the different environmental problems and the economic consequences of government intervention. The aim of this chapter is to analyse the environmental and economic effects of restricting environmental indicators, using a system of emission permits in an applied general equilibrium (AGE) model for the Netherlands. Moreover, special attention is paid to the differences between environmental indicators, the interaction of different environmental policies and the extent of tradeability of emission permits. Since economy-wide effects can be expected from environmental restrictions, using an AGE model is appropriate (Bergman, 1991). In addition, the AGE framework is well suited to quantify the causal relationship linking the economy and environment, since both direct and indirect effects are taken into account while the consumption and production structure in the model allows for proper substitution.

The policy simulations in this chapter determine the economic effects of restricting environmental indicators, taking into account all relevant contributing emissions. Shadow prices of restrictions on environmental indicators are calculated. It is shown that the economic effects of quantitative restrictions depend on emission coefficients, substitution possibilities and relative economic magnitude of the variables to which emissions are attached. For this purpose, the AGE model contains a great level of detail with respect to emissions to take into account the large differences that exist between different industries and consumption. Dellink et al. (1999) also apply the concept of environmental indicators to determine possible sustainable economic structures for the Netherlands, using an input-output type of optimisation model. Other AGE studies on the consequences of environmental policies are less detailed (see Wajsman, 1995, for an overview) and have not focused on environmental indicators but mainly on the restriction of just one or a few emissions (see for example Larsen (1997) on NO_x; Boyd et al. (1995), Böhringer and Rutherford (1997) and Conrad and Schröder (1991) on CO_2; and Boyd and Krutilla (1992) on SO_2 and NO_x). This chapter also shows the interaction effects when policy targets for different environmental indicators are achieved simultaneously. Shadow prices of restrictions on environmental indicators turn out to be mutually dependent when different indicators are related to the same economic variables. Dessus and Bussolo (1998) also look at a wide range of emissions but their simulations only consider a reduction of single emissions. Although Bergman (1991) determines the effects of a simultaneous reduction of CO_2, NO_x and SO_x emissions, shadow prices of all emissions and the interaction of environmental policies are not considered. Finally, this chapter deals with the potential benefits of a system of tradeable emission permits over a system of non-tradeable permits at a national level. The results show that the magnitude of these benefits differ between emissions. Although there is a vast amount of literature on this topic (see e.g., Baumol and Oates, 1988) most studies fail to quantify the potential benefits (for an exception see Rendleman et al., 1995).

In Section 5.2 the distribution of emissions and environmental indicators over the Dutch economy is elaborated. Section 5.3 explains the modelling of emission permits within the AGE model. Section 5.4 translates environmental targets into quantitative restrictions and presents the policy simulations. The results of the different simulations will be elucidated in Section 5.5. Finally, Section 5.6 provides a summary and general conclusions.

5.2 Distribution of emissions and environmental indicators over the economy

In this chapter, the environmental indicators adopted in Chapter 4 are applied as an inventory framework of current environmental problems in the Netherlands. Environmental indicators for the following phenomena are considered: greenhouse effect, acidification, eutrophication, and accumulation of waste. To quantify each indicator, nine specific emissions are aggregated using indicator equivalents. The direct contribution of the different economic agents in the Netherlands to emissions and environmental indicators in 1993 is shown in Table 5.1, which gives an idea of the distribution of the different environmental indicators over economic activities. However, this picture is incomplete since only direct emissions are taken into account. If, for example, an industry hardly generates pollution itself, it might use intermediate inputs, the production of which is polluting. It is therefore not accurate to compare the direct contribution to environmental damage by individual industries with economic variables like the contribution to national income, trade surplus or employment (see e.g., de Haan and Keuning, 1995 and 1996). In order to identify the links between economic activity and environment, indirect effects should also be taken into account.

A different point of view on the links between economic activity and environment is provided by Table 5.2 that shows to what extent emissions are related to individual inputs and aggregate output by industries, and to consumer goods and aggregate consumption by consumers. Emissions contributing to the greenhouse effect are mainly related to inputs by industries and consumer goods (fuels). Acidification is related to inputs by industries and consumer goods as well as aggregate output of industries. Eutrophication and to a greater extent waste accumulation are mainly related to aggregate output of industries and aggregate consumption. Hence, the table shows large differences in the links between emissions and economic variables. For individual industries, these differences (not shown here) are even larger. Inputs and individual consumer goods are easier to substitute than output and aggregate consumption. Moreover, substitution possibilities also differ between different industries. Hence, if the aim is to reduce emissions, different effects can be expected due to different substitution possibilities of the economic variables to which emissions are linked.

Tables 5.1 and 5.2 show that the distribution of emissions over the economy is diverse, both with respect to economic agents and with respect to the economic variables to which emissions are linked. In order to take into account this diversity at a sufficient detailed level and to allow for feed back effects and substitutability, an AGE model is the appropriate tool to identify the links between economic activity and the environment.

Table 5.1 *Distribution of emissions and environmental indicators, summarised for industries and consumers in the Netherlands (1993; % between parentheses)*[a]

Emission **Indicator**	Agriculture		Agribusiness		Other industries		Public utilities		Services		Consumption		**Total**	
CO_2	10179		5292		44412		39141		26012		36205		**161241**	**(88.7)**
N_2O	6959		62		3429		84		925		1998		**13458**	**(7.4)**
CH_4	4942		6		972		878		138		143		**7079**	**(3.9)**
GHG	**22080**	**(12.1)**	**5361**	**(2.9)**	**48814**	**(26.9)**	**40102**	**(22.1)**	**27074**	**(14.9)**	**38346**	**(21.1)**	**181777**	**(100.0)**
NO_x	437		356		2734		1372		3423		3746		**12068**	**(39.8)**
SO_2	34		56		3593		831		824		145		**5483**	**(18.1)**
NH_3	11765		55		284		0		1		655		**12760**	**(42.1)**
ACID	**12236**	**(40.4)**	**467**	**(1.5)**	**6611**	**(21.8)**	**2203**	**(7.3)**	**4247**	**(14.0)**	**4546**	**(15.0)**	**30311**	**(100.0)**
N	628		29		52		19		114		133		**976**	**(45.5)**
P	710		61		73		1		193		133		**1169**	**(54.5)**
EUT	**1338**	**(62.4)**	**90**	**(4.2)**	**125**	**(5.8)**	**20**	**(0.9)**	**307**	**(14.3)**	**266**	**(12.4)**	**2145**	**(100.0)**
WST	**707**	**(3.3)**	**1741**	**(8.2)**	**8362**	**(39.3)**	**262**	**(1.1)**	**4428**	**(20.7)**	**5845**	**(27.4)**	**21345**	**(100.0)**

[a] Greenhouse gases (GHG) in mln kg CO_2 equivalents, acidification (ACID) in mln acid equivalents, eutrophication (EUT) in mln kg N equivalents, and waste accumulation (WST) in mln kg.

Source: CBS-6 (1996) and own calculations.

Table 5.2 *Emissions and environmental indicators linked to inputs, output, consumer goods and aggregate consumption in the Netherlands (1993; % between parentheses)*[a]

	Industries				Consumption				**Total**	
Emission	Inputs		Aggregate output		Consumer goods		Aggregate consumption			
Indicator										
CO_2	115704		9331		34605		1600		**161241**	**(88.7)**
N_2O	1195		10265		1998		0		**13458**	**(7.4)**
CH_4	134		6802		143		0		**7079**	**(3.9)**
GHG	**117033**	**(64.4)**	**26398**	**(14.5)**	**36746**	**(20.2)**	**1600**	**(0.9)**	**181777**	**(100.0)**
NO_x	7939		383		3702		44		**12068**	**(39.8)**
SO_2	4358.		980		145		0		**5483**	**(18.1)**
NH_3	574		11531		655		0		**12760**	**(42.1)**
ACID	**12871**	**(42.5)**	**12894**	**(42.5)**	**4502**	**(14.9)**	**44**	**(0.1)**	**30311**	**(100.0)**
N	272		571		60		73		**976**	**(45.5)**
P	387		650		133		0		**1169**	**(54.5)**
EUT	**659**	**(30.7)**	**1221**	**(56.9)**	**193**	**(9.0)**	**73**	**(3.4)**	**2145**	**(100.0)**
WST	**0**	**(0.0)**	**15500**	**(72.6)**	**0**	**(0.0)**	**5845**	**(27.4)**	**21345**	**(100.0)**

[a] See Table 5.1.

Source: CBS-6 (1996) and own calculations.

5.3 Model characteristics

In this chapter the model described in Chapter 2 is used, calibrated on the 1993 data set. This section develops the modelling of emission permits in the AGE model[1]. First, a restriction on one environmental indicator related to aggregate output in an industry is developed. This is extended to the case where an environmental indicator is also related to inputs. Next, the case of tradeable emission permits is taken into account. Finally, a restriction on multiple environmental indicators is considered.

5.3.1 Modelling restrictions on environmental indicators

Environmental indicators EN_e from a set E = {1,2,3,4} are expressed in indicator equivalents:

$$EN_e = \sum_{b \in B} \sum_{g \in G} \psi^{IN}_{e,g,b}.IN_{g,b} + \sum_{b \in B} \psi^{Y}_{e,b}.Y_b + \sum_{g \in G} \psi^{X^{con}}_{e,g}.X^{con}_g + \psi^{CON}_e.CON \qquad \forall e \in E \tag{5.1}$$

where ψ are emission coefficients expressed in indicator equivalents for intermediate inputs ($IN_{g,b}$), aggregate output (Y_b), consumer goods (X^{con}_g) and aggregate consumption (CON). The policy simulations in this chapter adopt a system of emission permits expressed in indicator equivalents for each environmental indicator. As equation (5.1) shows, this implies a restriction on demand of inputs and supply of aggregate output by industries and a restriction on demand for consumer goods and aggregate consumption by consumers, since emissions are linked to these economic variables proportionally.

First, consider for each industry a restriction on one environmental indicator that is related to aggregate output only. Emission permits related to aggregate output by industries are modelled as a restriction on aggregate output inducing a level of emissions equal to the number of permits (expressed in indicator equivalents). Since aggregate output is restricted, a 'rent' ($RENT^{Y}_{e,b}$) occurs, which is equal to the difference between the market value and shadow value of aggregate output (see Hertel and Tsigas, 1991). The rent enters the AGE model, ensuring the zero profit condition holds. Hence, the zero profit condition of the basic

[1] In this chapter the reduction of environmental indicators is considered. Hence, use of the term 'environmental indicator permit' might be more appropriate. Since environmental indicators are a weighted sum of individual emissions, the more commonly used term 'emission permit' is preferred here.

model (equation I.22 in Appendix I) is adjusted accordingly[2].

$$WY_b.Y_b = WAIN_b.AIN_b + WAEN_b.AEN_b + WAPR_b.APR_b + RENT^Y_{e,b} \quad e \in E; \quad \forall\, b \in B \quad (5.2)$$

where $W..$ are prices, AIN_b is aggregate intermediate materials input, AEN_b is aggregate intermediate energy input, and APR_b is aggregate factor input. In the case of a restriction on one indicator, the rent represents the shadow value of the permitted indicator equivalents related to aggregate output. The shadow price per emission permit (*WEN*) in each industry can therefore be calculated as:

$$WEN^Y_{e,b} = \frac{RENT^Y_{e,b}}{\overline{EN^Y_{e,b}}} = \frac{RENT^Y_{e,b}}{\psi^Y_{e,b}.Y_b} \qquad e \in E; \forall b \in B \qquad (5.3)$$

This shadow price is equal to the value of the last indicator equivalent that has been reduced (marginal cost of reducing the environmental indicator).

5.3.2 Shadow price equalisation

In this chapter, restrictions are set on environmental indicators which, in industries, are not only related to aggregate output but also to inputs. For example, take the following restricted environmental indicator $\overline{EN}$:

$$\overline{EN_{e,b}} = \sum_{g \in G} \left(\psi^{IN}_{e,g,b}.IN_{g,b} \right) + \psi^Y_{e,b}.Y_b \qquad e \in E; \forall b \in B \qquad (5.4)$$

A reduction of one environmental indicator for each industry can be achieved by reducing emissions related to aggregate output as well as inputs. A restriction on emissions related to inputs is modelled similarly as a restriction on aggregate output. Again a rent occurs, being the difference between the market value and shadow value of an input. Since substitution is possible, the magnitude of the reductions will not be equal in each direction. A

2 Basically, an emission permit related to output is modelled exactly the same as the supply quota modelled in Chapter 3. The quota rent, in case of a supply quota, is related to output while in case of an emission permit, the quota rent is related to emissions.

reduction of emissions related to inputs through substitution by other inputs, for example, might be less costly than reducing emissions related to aggregate output. A least cost solution implies a reduction of emissions related to inputs and aggregate output by each industry such that shadow prices of permits related to inputs and aggregate output (marginal costs) will be equalised. Therefore, when a reduction target for one environmental indicator is set in each industry, the following shadow price equalisation rule *within agents* applies:

$$WEN^{Y}_{e,b} = WEN^{IN}_{e,g,b} = WEN^{IN}_{e,h,b} \qquad e \in E;\ g \neq h;\ \forall b \in B;\ \forall g,h \in G \quad (5.5)$$

In addition to (5.3) we have (5.6):

$$WEN^{IN}_{e,g,b} = \frac{RENT^{IN}_{e,g,b}}{\psi^{IN}_{e,g,b}.IN_{g,b}} \qquad e \in E;\ \forall b \in B;\ \forall g \in G \quad (5.6)$$

and the zero profit conditions for intermediate material and energy demand that replace I.23 and I.24 in the basic model:

$$WAEN_b.AEN_b = \sum_{g \in S_{en}} WIN_{g,b}.IN_{g,b} + \sum_{g \in S_{en}} RENT^{IN}_{e,g,b} \qquad e \in E;\ \forall b \in B \quad (5.7)$$

$$WAIN_b.AIN_b = \sum_{g \in S_{mat}} WIN_{g,b}.IN_{g,b} + \sum_{g \in S_{mat}} RENT^{IN}_{e,g,b} \qquad e \in E;\ \forall b \in B \quad (5.8)$$

5.3.3 Tradeable emission permits

A restriction on emissions related to consumer goods and aggregate consumption is modelled similarly as a restriction on inputs and aggregate output in industries. The shadow price equalisation rule *within agents* also applies to consumption, implying that the shadow price of emission permits related to consumer goods and aggregate consumption should be equal. Since industries and consumers within the Dutch economy contribute to environmental problems to a different extent, shadow prices are likely to differ when each industry and consumer has to reduce emissions to the same extent[3]. This scenario could also be called a 'command-and-control' regulatory approach (see Rendleman et al., 1995) where emission permits are non-tradeable.

It is also possible that quantitative restrictions take the form of a system of tradeable emission permits. For example, assume all industries together face the following restriction:

$$\overline{EN_e} = \sum_{b \in B} \sum_{g \in G} \left(\psi^{IN}_{e,g,b} . IN_{g,b} \right) + \sum_{b \in B} \psi^{Y}_{e,b} . Y_b \qquad e \in E \qquad (5.9)$$

This restriction on one environmental indicator for all industries together can be achieved by reducing emissions related to inputs and aggregate output in different industries. Industries with low shadow prices are likely to sell their emission permits to industries with high shadow prices. Hence, by trading emission permits, under such a 'market-based' system, emission permit prices will be equalised *between agents*:

$$WEN^{Y}_{e,b} = WEN^{IN}_{e,g,b} = WEN^{IN}_{e,g,c} = WEN^{Y}_{e,c} \qquad e \in E;\, b \neq c;\, \forall g \in G;\, \forall b,c \in B \quad (5.10)$$

This equalisation rule *between agents* can be extended to consumption when emission permits related to consumer goods and aggregate consumption are taken into account.

In Appendix XII it is shown that given a certain emission reduction related to an input in one industry, the shadow price of an emission permit related to this input is lower, the higher emission coefficients and substitution elasticities are, and the smaller the cost share of an input is. Generalised to the whole economy this implies that shadow prices of restrictions on emissions related to certain economic variables are lower, the higher the emission coefficients and substitution possibilities are, and the smaller cost shares of the variables are.

5.3.4 Restrictions on multiple environmental indicators

In addition to a restriction on single environmental indicators, environmental indicators can be restricted simultaneously. When more environmental indicators are restricted simultaneously, equation (5.9) and (5.10) hold for each restricted environmental indicator.

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[3] In the AGE model, consumers and each industry are represented by one agent. However, in reality there is also heterogeneity between different consumers and firms within industries. Therefore, the efficiency gain of a system of tradeable emission permits is under-estimated in the chapter.

Moreover, since the rent that occurs now is divided over different restricted environmental indicators, zero profit conditions need to be adjusted accordingly:

$$WY_b.Y_b = WAIN_b.AIN_b + WAPR_b.APR_b + \sum_{e \in E} RENT^{Y}_{e,b} \qquad \forall b \in B \tag{5.11}$$

$$WAEN_b.AEN_b = \sum_{g \in S_{en}} WIN_{g,b}.IN_{g,b} + \sum_{e \in E} \sum_{g \in S_{en}} RENT^{IN}_{e,g,b} \qquad \forall b \in B \tag{5.12}$$

$$WAIN_b.AIN_b = \sum_{g \in S_{mat}} WIN_{g,b}.IN_{g,b} + \sum_{e \in E} \sum_{g \in S_{mat}} RENT^{IN}_{e,g,b} \qquad \forall b \in B \tag{5.13}$$

When different environmental indicators are related to the same economic variables, the restriction on an additional indicator will be less restrictive than the restriction on a single indicator. The rent is subdivided over different indicators, which implies that shadow prices of different emission permits are mutually dependent. For each indicator, the shadow price equalisation rules hold.

5.3.5 *Caveats*

The model presented has some caveats, which are elucidated before the simulations are presented. First, although emissions are taken into account at a very detailed level, there are still improvements possible. Due to insufficient information, it is assumed that waste emissions by industries are related to aggregate output, while it seems clear that part of it is related to certain inputs. Moreover, not all harmful emissions are taken into account (e.g., pesticides, dioxin, heavy metals, etc.). Second, abatement functions are not present in the model. A reduction of emissions can therefore only take place by reducing inputs and aggregate output by industries and consumer goods and aggregate consumption by consumers. In some other studies abatement functions are taken into account, based on ad hoc assumptions (Bergman, 1991) or embedded in the SAM (Nestor and Pasurka, 1995). At the level of detail applied in this chapter, however, data is lacking to derive a consistent set of abatement functions for all emissions by all activities that are considered. An alternative way of emission reduction would be to represent an industry by specifying multiple technologies (see Chapter 6 and Böhringer, 1998). Third, we recognise that in our small open economy model we fail to account for trade-related impacts on global emissions. Finally, environmental quality is not an argument in the utility function of the representative household. This makes it impossible to determine 'true' welfare effects (including environmental quality). We choose not to include environmental quality in the utility function because the implicit weights necessary for incorporation are lacking.

5.4 Policy simulations

When it comes to formulation of environmental policy, authorities often refer to a reduction in flows of emissions. The Dutch government has developed quantitative environmental policy targets while dividing its environmental policy into different indicators (see MVROM, 1996 and 1997). This chapter considers a reduction of the greenhouse effect, acidification, eutrophication and waste accumulation. Quantitative targets are modelled by introducing emission permits expressed in indicator equivalents. Emissions permits are chosen as policy variable to ensure a 'first-best' solution. Alternatively, an endogenously determined emission tax could be introduced which, theoretically, generates equivalent results[4].

The aim of the simulations in this chapter is to quantify the main causal relationships linking the Dutch economy and the environment and to compare the potential economic consequences of restricting different environmental indicators. In reality, for each indicator policy goals are set, referring to different reduction rates, base years and time horizons (see e.g., Centraal Planbureau, 1997). In this chapter, economic and environmental data of 1993 are used. To facilitate comparison, in the different simulations an equal reduction of environmental indicators relative to 1993 is set as imaginary policy goal. The first set of simulations determines the effects of a 10 per cent reduction of each single environmental indicator. Moreover, for each environmental indicator the effects of a system of tradeable and non-tradeable emission permits are compared[5]. Finally, it will be investigated what the effects are when policy goals are set for two environmental indicators simultaneously. The

4 Emission taxes and emission permits are theoretically equivalent in the short run when tax revenues are given the same destination as the value of the emission permits. From a policy point of view, however, there are many differences (see Baumol and Oates, 1988, p. 178-181).

5 Under the non-tradeable 'command-and-control' approach, the sum of emissions by consumption and each industry is equal to the target level that is set for consumption and each industry. Hence shadow prices of emission permits are different. Under the tradeable 'market-based' approach, the sum of emissions over all industries and consumption is equal to the national emission target while shadow prices are equalised between industries and consumption. The value of the emission permits or 'rents' are transferred lump-sum to consumers and industries.

interaction of a greenhouse gas restriction and an acidification restriction will be evaluated under the assumption of tradeable emission permits.

5.5 Results

Shadow prices and emission reduction levels

The effects of a 10 per cent reduction of each single environmental indicator on shadow prices and reduction levels for individual industries and consumption are presented in Tables 5.3 and 5.4.

Table 5.3 *Shadow prices of environmental indicators for selected industries and consumption at 10% environmental indicator reduction (in 1993 guilder per indicator equivalent[a])*

Simulation:	10% reduction GHG		10% reduction ACID		10% reduction EUT		10% reduction WST	
Shadow price for	not tradeable	tradeable	not tradeable	tradeable	not tradeable	tradeable	not tradeable	tradeable
Dairy farming	0.21	0.04	0.23	0.18	1.42	1.52	4.05	3.37
Pig farming	0.16	0.04	0.08	0.18	0.83	1.52	4.62	3.37
Horticulture under glass	0.09	0.04	1.44	0.18	69.03	1.52	11.95	3.37
Petroleum industry	0.01	0.04	0.03	0.18	11.08	1.52	7.24	3.37
Fertiliser industry	-0.02	0.04	0.19	0.18	1.80	1.52	0.48	3.37
Basic metal industry	0.10	0.04	0.70	0.18	52.50	1.52	2.16	3.37
Electricity supply	-0.02	0.04	-0.04	0.18	36.73	1.52	3.35	3.37
Consumption	0.24	0.04	1.43	0.18	47.03	1.52	12.93	3.37
Mean shadow price	0.13	0.04	1.03	0.18	21.43	1.52	9.41	3.37

[a] Indicator equivalents are defined as: Greenhouse gases (GHG) in kg CO_2 equivalent, acidification (ACID) in mole H^+, eutrophication (EUT) in kg N equivalent, waste accumulation (WST) in kg waste.

The tables show that under a system of tradeable permits, shadow prices are equal between agents, while under a system of non-tradeable permits, reduction levels are equal. The permit prices for 1 kg CO_2 equivalent (greenhouse effects), 1 mole H^+ (acidification), 1 kg N equivalent (eutrophication) and 1 kg waste (waste accumulation) at 10 per cent reduction of the concerning indicators are 0.04, 0.18, 1.52 and 3.37 guilders (1993) respectively, when permits are tradeable. Agents with the highest shadow prices under a system of non-tradeable permits will have the lowest reductions when permits are tradeable. Consumers, for example, face a shadow price of 0.24 guilders (1993) per kg CO_2 equivalent when permits are non-tradeable, which is almost twice the mean shadow price[6]. Clearly, consumers are willing to buy tradeable permits and thus reduce less greenhouse gases (only 3.7 per cent) than in case permits are non-tradeable (10 per cent). The fertiliser industry and petroleum industry, however, are likely to sell permits since it is cheap for these industries to reduce greenhouse gas emissions relative to other energy users.

Table 5.4 *Effects on environmental indicators for selected industries and consumption of 10% environmental indicator reduction (in % change from benchmark)*

Simulation:	10% reduction GHG		10% reduction ACID		10% reduction EUT		10% reduction WST	
Environmental indicator	not tradeable	tradeable	not tradeable	tradeable	not tradeable	tradeable	not tradeable	tradeable
Dairy farming	-10.0	-2.2	-10.0	-8.0	-10.0	-6.3	-10.0	-10.5
Pig farming	-10.0	-3.4	-10.0	-22.2	-10.0	-25.6	-10.0	-26.6
Horticulture under glass	-10.0	-11.7	-10.0	-0.5	-10.0	0.3	-10.0	-0.3
Petroleum industry	-10.0	-39.9	-10.0	-38.7	-10.0	-0.9	-10.0	-2.0
Fertiliser industry	-10.0	-24.0	-10.0	-11.5	-10.0	-10.1	-10.0	-35.9
Basic metal industry	-10.0	-4.9	-10.0	-1.6	-10.0	0.4	-10.0	-8.7
Electricity supply	-10.0	-14.9	-10.0	-4.6	-10.0	-0.7	-10.0	-7.0
Consumption	-10.0	-3.7	-10.0	-3.1	-10.0	-0.7	-10.0	-4.7
Total emissions	-10.0	-10.0	-10.0	-10.0	-10.0	-10.0	-10.0	-10.0

The results also show that in the case of non-tradeable permits, negative shadow prices are feasible. For example in the case of acidification reduction, a shadow price of -0.04 guilders per mole H^+ for the electricity supply industry implies that a 10 per cent reduction of acidification is not a maximum restriction but a minimum restriction. Without a restriction for electricity supply, acidification would be reduced by more than 10 per cent. This is due to indirect effects, because consumption and other industries demand less energy inputs as result of their own acidification restriction[7].

In general, the results in Tables 5.3 and 5.4 show that not necessarily only agents with large emissions are affected (e.g., basic metal industry). However, to a larger extent agents with high emission coefficients are affected (e.g., fertiliser and petroleum industry with

6 The mean shadow price is calculated as the total shadow value of all restrictions (sum of rents) divided by the total restricted level of emissions. Hence, it is a perfect weighted mean shadow price, using emissions as weights.

7 This peculiar result is due to the fact that emission restrictions are modelled as a strict equality. Negative shadow values could be avoided by introducing a 'smaller-than-or-equal' equality. In AGE models this is feasible by means of defining a mixed complementarity problem (see e.g., Löfgren and Robinson, 1999a). However, to ensure a 10 per cent indicator reduction at a national level, consistent with the other simulations, it is not applied in this chapter.

respect to greenhouse gases and dairy farming and pig farming with respect to eutrophication). This confirms the analytical results obtained in Appendix XII. Figure 5.1 shows that the shadow price of a restriction on greenhouse gas emissions increases when the reduction level is increased. Clearly, when permits are tradeable, shadow prices are much lower which implies that tradeability lowers the costs of reducing emissions. Moreover, the difference is greater when the reduction level increases.

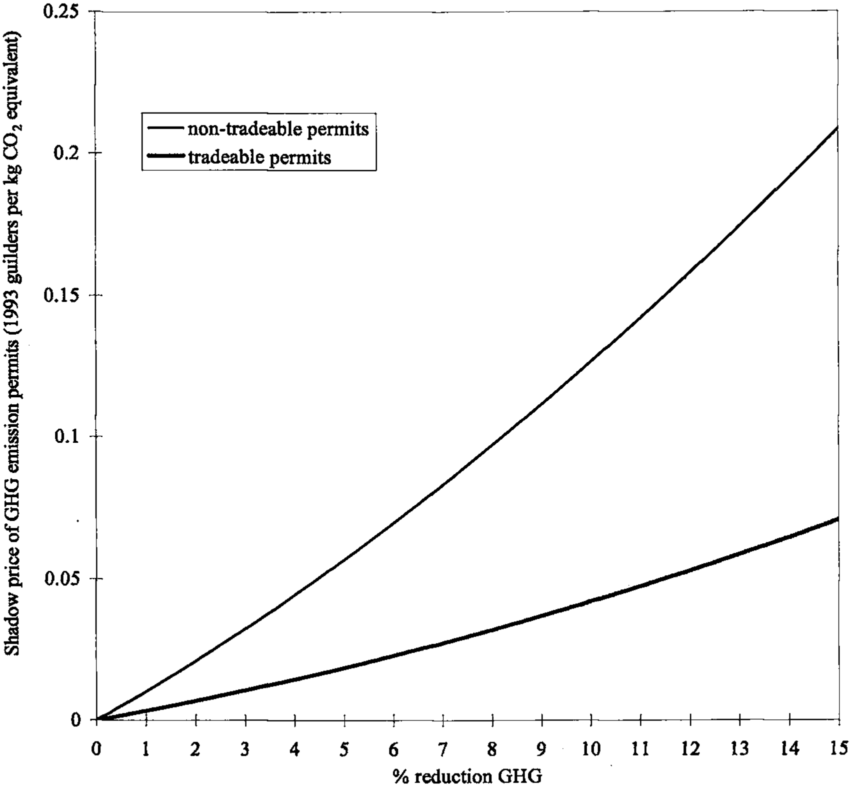

Figure 5.1: *Shadow price of GHG emission permit with and without tradeable permits*

Production

Table 5.5 shows the effects on production in some selected industries. When permits are not tradeable, the consequences for production depend on the possibility of substitution within industries. Horticulture under glass, for example, only reduces production by 2.1 per cent while greenhouse gas emissions have to be reduced by 10 per cent. Apparently, there is enough substitution between inputs to avoid a large production reduction. If, however, emissions are mainly related to aggregate output, like acidification and eutrophication in agriculture and waste accumulation in all industries, substitution possibilities are hardly available and a reduction of production is inevitable.

When permits are tradeable, differences between industries are larger. Industries with high emission coefficients are affected most by a 10 per cent reduction of greenhouse gases when permits are tradeable. In the fertiliser industry and petroleum industry, production decreases by 22.5 per cent and 9.5 per cent respectively. In the case of acidification and eutrophication reduction, agricultural industries reduce production most. Some industries are also affected indirectly, when the demand for commodities produced by these industries decreases. In the case of acidification and eutrophication, for example, agricultural industries will demand less input, which clearly affects the compound feed industry. The same applies for electricity supply in the case of a reduction of greenhouse gases.

Table 5.5 *Effects on production by selected industries of 10% environmental indicator reduction (% change from benchmark)*

Simulation:	10% reduction GHG		10% reduction ACID		10% reduction EUT		10% reduction WST	
Production by	not tradeable	tradeable	not tradeable	tradeable	not tradeable	tradeable	not tradeable	tradeable
Dairy farming	-9.9	-2.1	-9.7	-7.7	-9.0	-5.6	-10.0	-10.5
Pig farming	-9.7	-2.7	-10.0	-22.2	-10.0	-25.6	-10.0	-26.6
Horticulture under glass	-2.1	-2.5	-2.1	0.2	-4.1	0.3	-10.0	-0.3
Compound feed industry	-11.0	-2.5	-11.2	-15.0	-9.9	-18.0	-10.0	-25.3
Petroleum industry	-4.3	-9.5	-5.1	-10.2	-3.4	0.1	-10.0	-2.0
Fertiliser industry	-9.4	-22.5	-9.8	-11.2	-8.5	-8.9	-10.0	-35.9
Basic metal industry	-6.8	-3.7	-8.3	-1.2	-8.8	0.4	-10.0	-8.7
Electricity supply	-11.9	-10.8	-9.1	-3.1	-7.6	-0.5	-10.0	-7.0
Gas distribution	-10.0	-6.0	-9.6	-1.3	-4.7	-0.5	-10.0	-3.9

Domestic use and trade of commodities

Table 5.6 shows the effects on domestic use (total use within the Netherlands) of some selected commodities. The results show that in the case of greenhouse gas reduction as well as in the case of acidification reduction, domestic use of the polluting commodities 'other fuels for heating' (mainly petroleum and fuel oil) and 'coal' are reduced most. 'Distributed gas' and 'fuels for vehicles' are reduced to a much lesser extent. In the case of eutrophication reduction, clearly domestic use of 'fertiliser' and 'compound feed' are reduced.

The effects on trade are presented in Table 5.7. On the one hand, it can be concluded that exports (imports) of commodities that are polluting when used domestically increase (decrease) as is the case for natural gas and coal, in the case of greenhouse gases or acidification reduction. On the other hand, exports (imports) of commodities whose domestic production is polluting, decrease (increase), as is the case for fertiliser, compound feed and pigs[8]. For commodities like fuels for vehicles and other fuels for heating, both effects occur. These trade effects occur since restrictions are set on domestic use. If similar environmental restrictions were in force in the EU or the rest of the world, these effects would be less pronounced.

Table 5.6 *Effects on domestic use of selected commodities of 10% environmental indicator reduction (% change from benchmark)*

Simulation:	10% reduction GHG		10% reduction ACID		10% reduction EUT		10% reduction WST	
Domestic use of	not tradeable	tradeable	not tradeable	tradeable	not tradeable	tradeable	not tradeable	tradeable
Fuels for vehicles	-8.1	-3.5	-10.7	-3.9	-8.7	-0.8	-13.5	-7.0
Coal	-11.3	-14.6	-11.0	-6.9	-10.8	-0.5	-11.6	-9.0
Natural gas	-10.8	-9.2	-10.3	-3.0	-7.1	-0.8	-12.0	-7.8
Distributed gas	-10.0	-6.0	-9.6	-1.3	-4.7	-0.5	-10.7	-3.9
Other fuels for heating	-16.7	-18.0	-12.6	-15.5	-9.7	-0.7	-11.4	-13.1
Electricity	-13.4	-10.2	-9.8	-3.0	-7.7	-0.6	-10.6	-7.5
Compound feed	-11.4	-2.6	-11.8	-15.7	-11.3	-18.8	-11.9	-24.5
Fertiliser	-11.3	-8.3	-10.6	-7.8	-10.6	-6.5	-14.4	-19.8

Welfare

Table 5.8 shows the welfare improvement of a system of tradeable emission permits over a system of non-tradeable permits when emissions are reduced by 10 per cent. For example, a reduction of greenhouse gases by 10 per cent will decrease welfare by 2944 million guilders (1993) without tradeable permits while in the case of tradeability the welfare loss will be 1850 million guilders (1993).

8 For pigs the homogeneity assumption is valid which implies that pigs are either imported or exported. Initially pigs are exported and the domestic price is equal to the export price. Acidification and eutrophication reduction leads to a fall in domestic production of pigs and hence a decrease of pig export. At an acidification and eutrophication reduction of 6.5 per cent and 5.6 per cent respectively, pig export is reduced to zero. In the model there is a positive difference between the import (c.i.f.) and export (f.o.b.) price because of market margins. When acidification and eutrophication is reduced by 10 per cent, the domestic price happens to lie between the import and export price and hence trade is absent. Additional calculations show that the domestic price is equal to the import price when acidification and eutrophication are reduced by 18.1 per cent and 16.5 per cent respectively. At this point the Netherlands becomes a pig importer.

Table 5.7 *Effects on trade in selected commodities of 10% environmental indicator reduction (% change from benchmark)*

Simulation:	10% reduction GHG		10% reduction ACID		10% reduction EUT		10% reduction WST	
Trade	not tradeable	tradeable	not tradeable	tradeable	not tradeable	tradeable	not tradeable	tradeable
Net export								
Fuels for vehicles	-2.5	-12.5	-2.3	-13.4	-0.8	0.6	-8.3	0.4
Natural gas	13.8	11.1	14.9	5.9	14.2	3.2	-6.4	27.9
Other fuels for heating	2.0	-5.0	-1.1	-7.3	-0.1	0.5	-9.3	3.5
Fertiliser	-7.5	-31.3	-8.8	-12.8	-6.7	-10.1	-6.9	-45.5
Pigs	-56.3	-15.2	-46.4	-100[a]	-6.2	-100[a]	-3.8	-12.6
Net import								
Coal	-11.3	-14.6	-11.0	-6.9	-10.8	-0.5	-11.6	-9.0
Electricity	-57.6	2.5	-33.5	-2.9	-12.8	-3.1	-26.6	-20.6

a In these cases the Netherlands neither exports nor imports pigs (see also footnote 8).

The difference in welfare loss is the largest for eutrophication (5476 vs. 1060 million guilders). The large difference in eutrophication emission coefficients between agents, and consequently differences in shadow prices, offers scope for efficiency gains when a tradeable emission permits system is introduced. It should be noted that the potential benefit of a tradeable permit system is lower when transaction costs are considered (see Stavins, 1995).

Table 5.8 *Effects on welfare and exchange rate of 10% environmental indicator reduction*

Simulation:	10% reduction GHG		10% reduction ACID		10% reduction EUT		10% reduction WST	
Variable	not tradeable	tradeable	not tradeable	tradeable	not tradeable	tradeable	not tradeable	tradeable
Welfare[a]	-2944	-1850	-2592	-1777	-5476	-1060	-14270	-12315
Exchange rate[b]	0.99%	0.75%	-0.15%	1.11%	0.20%	0.84%	-4.23%	2.56%

a Welfare measured in 1993 million guilders.
b Exchange rate change in 1993 guilders per dollar.

Appendix XIII shows the welfare effects for the range of 0 to 15 per cent reduction of all environmental indicators. Reducing a certain level of acidification leads to the lowest welfare loss, while reducing waste emissions leads to the highest welfare loss. This can partly be explained by the extent of substitutability between commodities for industries and consumption. In the case of waste emissions and to a lesser extent of eutrophication, where emissions are related to aggregate output and aggregate consumption, substitution is hardly possible and a reduction of emissions will therefore be very costly. In the case of acidification and greenhouse gas emissions, however, a reduction can mainly be achieved by substituting zero or low emission commodities for high emission commodities. Moreover, in the latter case, emissions are widely distributed over all industries and consumers, which, especially in the case of tradeable emission permits, offers scope for an efficient allocation of the burden.

Environment

Table 5.9 shows that a 10 per cent reduction of greenhouse gases is achieved mainly by reducing CO_2 emissions, both in the case of non-tradeable and tradeable permits, while N_2O and CH_4 emissions are reduced to a lesser extent. Again, this is because the latter two emissions are more related to aggregate output while CO_2 is mainly related to inputs, which are easier to substitute. Clearly, a reduction of greenhouse gases also reduces acidification (and vice versa) since the underlying emissions are correlated (CO_2, NO_x and SO_2 are all related to fossil fuels). Eutrophication is much less related to the other environmental indicators, because emissions are mainly related to different inputs. Moreover, the main part of eutrophication is caused by a few agricultural industries.

Table 5.9 *Effects on emissions and environmental indicators of 10% environmental indicator reduction (% change from benchmark)*

Simulation:	10% reduction GHG		10% reduction ACID		10% reduction EUT		10% reduction WST	
Emission **Indicator**	not tradeable	tradeable	not tradeable	tradeable	not tradeable	tradeable	not tradeable	tradeable
CO_2	-10.3	-10.9	-10.3	-5.8	-8.7	-0.8	-12.2	-8.9
N_20	-7.3	-3.3	-7.2	-4.2	-8.2	-3.0	-10.6	-13.3
CH_4	-8.7	-2.8	-8.6	-7.9	-7.3	-7.9	-10.2	-11.3
GHG	***-10.0***	***-10.0***	**-10.0**	**-5.7**	**-8.6**	**-1.2**	**-12.0**	**-9.3**
NOx	-9.0	-7.4	-10.4	-5.3	-9.2	-0.8	-13.2	-9.0
SO_2	-10.0	-20.2	-10.1	-18.1	-9.8	-0.7	-12.3	-7.2
NH_3	-9.5	-2.5	-9.5	-11.0	-9.7	-7.9	-10.2	-16.0
ACID	**-9.4**	**-7.7**	***-10.0***	***-10.0***	**-9.5**	**-5.2**	**-11.8**	**-11.6**
N	-9.0	-3.3	-9.2	-8.5	-9.1	-8.2	-11.4	-15.0
P	-8.2	-2.7	-9.2	-9.6	-10.8	-11.5	-12.1	-20.5
EUT	**-8.6**	**-3.0**	**-9.2**	**-9.1**	***-10.0***	***-10.0***	**-11.8**	**-18.0**
WST	**-2.9**	**-1.1**	**-3.7**	**-1.1**	**-5.2**	**-0.9**	***-10.0***	***-10.0***

Interaction of environmental policies

The fact that environmental indicators are related also has consequences when two or more environmental policy goals are set simultaneously. For example, the introduction of a reduction of acidification will be less restrictive when a certain level of greenhouse gas reduction is already achieved. This effect is shown in Figure 5.2, in which the interaction between the emission permit prices of greenhouse gas and acidification is plotted. The starting point of this picture is a 10 per cent reduction of greenhouse gases, while emission permits are assumed tradeable. From Table 5.3 it was already concluded that at a 10 per cent reduction of greenhouse gases, the shadow price of a restriction on greenhouse gas emissions is 0.04 guilders (1993) per kg CO_2 equivalent. Moreover, at this point, acidification will be reduced by 7.7 per cent (see Table 5.9). Hence, the origin of the picture represents the point without a restriction for acidification and thus the permit price for acidification is zero.

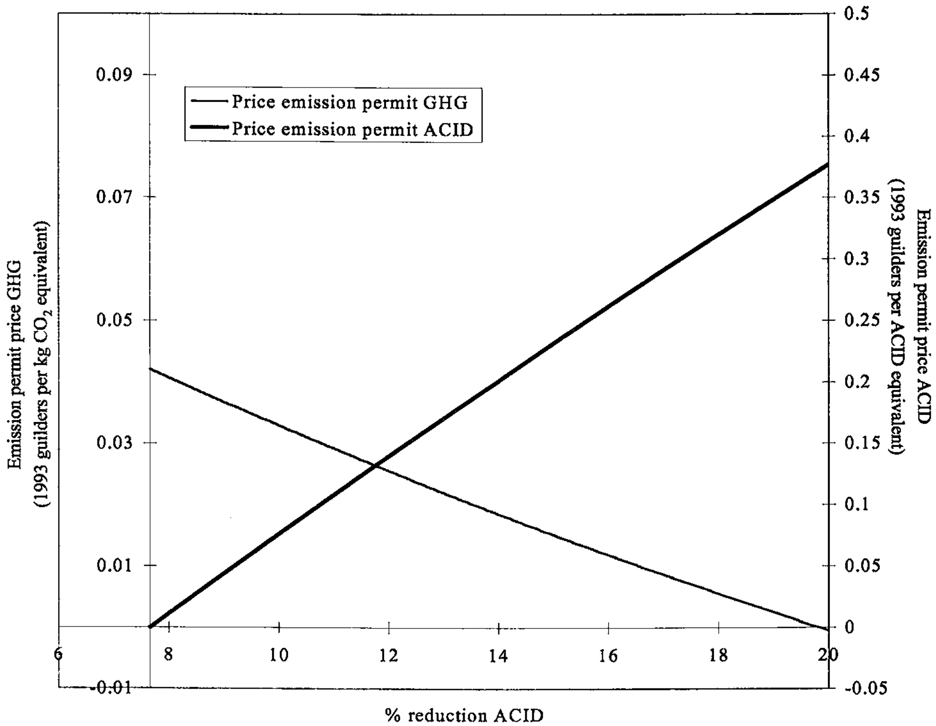

Figure 5.2: *Interaction emission permit prices GHG and ACID (at 10% GHG reduction) when permits are tradeable*

The picture shows that if the acidification restriction is set beyond 7.7 per cent reduction, the permit price for greenhouse gases will decrease while the permit price for acidification increases. Clearly, when the acidification reduction aim becomes increasingly restrictive, it takes over part of the greenhouse gas restriction. At 19.8 per cent acidification reduction, the restriction is such that the greenhouse gas policy goal is no longer restrictive and hence the shadow price of a restriction on greenhouse gases becomes zero or negative.

Table 5.10 shows the effects of a 10 per cent reduction of both greenhouse gas and acidification when permits are tradeable. Again, it is shown that in the case of a simultaneous 10 per cent reduction of both indicators, shadow prices of both restrictions are lower than in the case of a 10 per cent reduction of each indicator separately. The table also shows that the welfare loss of a restriction on acidification in addition to a restriction on greenhouse gases is relatively small. Finally, from Table 5.10 it can be concluded that the effects on environmental indicators by the different groups of industries and consumption in the case of a simultaneous emission reduction are less different than in the case of a reduction of indicators separately.

Table 5.10 *Effects on welfare, shadow prices and environmental indicators, summarised for industries and consumers of 10% GHG and ACID reduction, assuming tradeable permits*

Simulation:	10% reduction GHG		10% reduction ACID		10% reduction GHG and ACID	
Welfare[a]	-1850		-1777		-2144	
Shadow price[b]	GHG	ACID	GHG	ACID	GHG	ACID
	0.042	-	-	0.184	0.033	0.076
Environmental indicators[c]	GHG	ACID	GHG	ACID	GHG	ACID
Agriculture	-5.8	-2.5	-5.4	-11.4	-7.0	-7.2
Agribusiness	-9.7	-6.9	-5.4	-5.7	-9.9	-7.7
Other industries	-15.4	-20.3	-11.7	-18.5	-16.1	-22.1
Public utilities	-14.5	-14.9	-4.4	-4.5	-13.2	-13.5
Services	-5.9	-3.7	-2.5	-3.4	-5.6	-4.2
Consumption	-3.7	-3.4	-1.9	-3.1	-3.7	-3.9
Total	-10.0	-7.7	-6.1	-10.0	-10.0	-10.0

[a] See Table 5.8.
[b] See Table 5.3.
[c] See Table 5.1.

5.6 Summary and conclusions

This chapter analyses the environmental and economic effects of restricting greenhouse gases, acidification, eutrophication and waste accumulation. An AGE model is used, in which emissions are linked to inputs, aggregate output, consumer goods and aggregate consumption at a very detailed level. Attention is paid to the different effects of restricting single environmental indicators, the interaction effects of restricting different environmental indicators simultaneously and tradeability of emission permits.

The results in this chapter show large differences in welfare losses as result of restricting different environmental indicators, which can be explained by the extent to which inputs, aggregate output, consumer goods and aggregate consumption can be substituted. In the case of waste emissions and to a lesser extent of eutrophication, where emissions are related to aggregate output and aggregate consumption, substitution is hardly possible and a reduction of emissions will therefore be very costly. In the case of acidification and greenhouse gas emissions, however, a reduction can mainly be achieved by substitution of zero or low emission commodities for high emission commodities, which entails relatively low costs. Moreover, in the latter case, emissions are widely distributed over all industries and consumers, which, especially in the case of tradeable emission permits, offers scope for an efficient allocation of the emission reduction. These results emphasise the need for a very detailed emission matrix at a disaggregated level as applied in this chapter.

This chapter also shows that environmental policies might interact when different environmental indicators are related to the same economic variables. When two or more environmental policy goals are set simultaneously, individual restrictions are less restrictive and hence permit prices will be lower. In addition, the welfare loss of an additional environmental restriction is relatively small.

Finally, the simulations in this chapter show the potential benefits of a system of tradeable permits over a system of non-tradeable permits. When permits are tradeable, permit prices for 1 kg CO_2 equivalent (greenhouse effects), 1 mole H^+ (acidification), 1 kg N equivalent (eutrophication) and 1 kg waste (waste accumulation) at 10 per cent reduction of the concerning emissions are 0.04, 0.18, 1.52 and 3.37 guilders (1993) respectively. These are lower than the average shadow prices in the case of non-tradeability (0.13, 1.03, 21.43 and 9.41 respectively). The difference in welfare loss between non-tradeable and tradeable permits is largest in the case of eutrophication (5476 vs. 1060 million guilders), which is due to the large differences in eutrophication emission coefficients between agents.

The simulations give a good insight into the effects that stricter environmental policies might cause. Of course, the results are conditional on the model and data characteristics; e.g., functional forms, specification of agents and commodities, and the static nature of the model. More detail with respect to the links between emissions and economic variables is necessary (e.g., for waste emissions) to improve the simulation results of the model. In addition, the policy simulations themselves should be interpreted with care. To facilitate comparison, the applied reduction levels are chosen to be the same for each environmental indicator, which, most likely, is not the case in reality. Finally, a system of emission permits was chosen to simulate environmental policy. In reality, it can be hard to identify and quantify the emissions for each agent distinguished in this chapter.

From a policy perspective, the results in this chapter give insight into the potential effects of achieving different environmental policy goals. Since both direct and indirect effects are taken into account in the AGE framework used, the links between environmental problems and economic activity are placed in a broad perspective.

CHAPTER 6

ENDOGENOUS TECHNOLOGY SWITCHES IN DUTCH DAIRY FARMING WHEN ENVIRONMENTAL AND AGRICULTURAL POLICIES ARE RESTRICTIVE

Abstract

In this chapter an applied general equilibrium (AGE) model written in mixed-complementarity format is developed and used to analyse the effects of an increase in milk quota in the Netherlands when N emissions are restricted. The model combines the strengths of AGE models and mathematical programming models, which enables economy-wide policy analyses while technology switches are allowed. Results show that a welfare gain can be reached by increasing milk quota while keeping N emissions at the same level. Under such a policy change inactive N-extensive technologies in dairy farming become active and (partly) replace N-intensive technologies and output in other agricultural industries decreases.

6.1 Introduction

In order to be compatible with the General Agreement on Tariffs and Trade (GATT) Uruguay Round Agreement and to anticipate to future World Trade Organisation (WTO) agreements and enlargement of the EU after 2000, the EU reforms its Common Agricultural Policy (CAP), known as Agenda 2000 (Boots, 1999). Milk quota will be increased (1.5 per cent in the Netherlands), the intervention prices for butter and skimmed milk powder will be decreased by 15 per cent and income losses will (partly) be compensated by direct income payments (Agra Europe, 1999).

Some countries within the EU – Denmark, Sweden and the UK – proposed a more drastic dairy policy reform in 1998 in which quota abolition was the main objective (AgraFocus, 1998). One would have expected that the Netherlands, with probably one of the most competitive dairy industries in the EU, joined this group. However, they did not. The main reason for this is probably that the Netherlands is already confronted with an excess mineral supply of nitrate and phosphate. The Dutch government fears that quota abolition would lead to a strong growth in mineral production that would require additional environmental policy measures. In particular, the growth in N emissions is unacceptable given the EU Nitrates Directive. It is very likely, however, that an increase in milk quota, in combination with an N emission restriction, will lead to the application of new low-emission technologies. The purpose of this chapter is to analyse the effects of an increase in milk quota in the Netherlands when nitrogen (N) emissions are restricted, using an applied general equilibrium (AGE) model that considers the possible application of new technologies.

AGE models are used for agricultural and environmental policy analysis if economy-wide policy effects can be expected and are of interest. An AGE model is relevant in case of an increase in milk quota when total N emissions are restricted because of the linkages between dairy farming, the other agricultural industries (most agricultural industries have an N surplus) and the compound feed industry. In most AGE models, industries adopt a smooth well-behaved neoclassical production technology. Describing technologies this way can be criticised since policy changes can only lead to input substitution while technology switches cannot take place. Mathematical programming models on the other hand, allow for technology switches. Under the policy change mentioned above, it is likely that inactive, N-extensive technologies in dairy farming become active and (partly) replace N-intensive technologies (see Berentsen, 1998, for an application of a mathematical programming model for environmental policy analysis in Dutch dairy farming). A drawback of mathematical programming models is that they take input and output prices as exogenous.

In this chapter, both approaches are combined by formulating an AGE model as a non-linear mixed-complementarity (MC) problem. If an AGE model is written in MC format (AGE-MC model), it allows the standard features of the AGE approach (strict equalities) to be combined with mathematical programming features (inequalities) to specify technical restrictions or technologies more accurately. Moreover, it consistently takes into account that prices and technology mutually influence each other. It also makes it possible that more than one technology is operational at given prices.

The remainder of this chapter is organised as follows. Section 6.2 elaborates on the MC features of the AGE model developed. Special attention is given to the modelling of technology switches and the description of different technologies in dairy farming. Policy simulations are described in Section 6.3. Section 6.4 discusses the results of the simulations while Section 6.5 provides the results of some sensitivity analyses. Finally, Section 6.6 concludes with a summary and conclusions.

6.2 Model characteristics

A standard AGE model, as described in Chapter 2, can be formulated as a system of simultaneous (non-linear) equations, all of which are strict equalities. It consists of well-behaved neoclassical functions and a unique solution can be found with strictly positive prices, while all activities present in the benchmark year are active. The AGE-MC model in this chapter consists of a set of simultaneous (linear or non-linear) equations that are a mix of strict equalities and inequalities, with each inequality linked to a bounded variable in a complementary slackness condition (see also Rutherford, 1995; Folmer et al., 1995; Gunning and Keyzer, 1995). Hence, the AGE-MC model, combines the standard features of the AGE approach (strict equalities) with mathematical programming features (inequalities) to specify technical restrictions or technologies more accurately. Examples of AGE-MC applications for agricultural and environmental policy analysis are scarce. Böhringer (1998) uses a stylised model to show possible technology switches in electricity production in the case of emission taxes and Löfgren and Robinson (1999a) model inequality constraints on agricultural factor use in a simple AGE model of Egypt. Gohin and Guyomard (1999) use inequality constraints to model EU dairy policy instruments. Recent advances in software development make it possible to solve large-scale AGE-MC models (see Rutherford, 1995)[1]. This section provides the complementary-slackness conditions applied in the model to specify discrete technology switches in dairy farming and restrictions on N emissions in agriculture[2]. Finally, the data for both the active and latent Leontief technologies in dairy farming are described.

6.2.1 Technology switches in dairy farming

In most AGE models, each industry is represented by a smooth well-behaved neoclassical production technology that is fully specified by the original data set and exogenous parameters, using a calibration procedure. Since emissions do not have a price, they cannot be calibrated as an economic input. Hence, emissions are often assumed to be related to inputs and/or output. If emissions are mainly related to output, as is the case for N emissions in livestock farming, emission reduction can only be achieved by output reduction. In reality,

1 The model is written and solved in the software package GAMS (see Brooke et al. (1988), using MILES (a Mixed Inequality and non-Linear Equation Solver) as MC solver (see Rutherford, 1995).

2 The same approach could have been used to model under-utilisation of milk quota (see Gohin and Guyomard, 1999). However, milk quota in the Netherlands is binding, which is reflected by a high quota price.

however, it is feasible that new low-emission technologies come to the fore. Since these technologies are not observed in the initial situation, they are not in the domain of the single calibrated technology. In this chapter, this gap in the conventional calibration procedure is avoided by specifying different technologies where each technology is characterised by a different emission-input-output mix. This allows for technology switches, which make it feasible to reduce emissions without necessarily reducing output[3].

"There is no straightforward way to formulate neoclassical production technology so that production and input demand functions are defined mathematically when an activity is zero. The domains of the production functions and first-order conditions do not include zero for factor inputs" (Löfgren and Robinson, 1999b, footnote 6). Hence, it is difficult to allow a production activity to close down or start up, using a neoclassical specification. Instead a set of Leontief technologies can be used, also called 'activity analysis' specification (Löfgren and Robinson, 1999a) or 'bottom-up' technology (Böhringer, 1998).

Therefore, technology switches in dairy farming are modelled, using a Leontief specification for both active (old) and latent (new) technologies. Hence, demand for inputs $IN_{g,t}$ for each technology t is a linear function of output Y_t according to input-output coefficients $\delta_{g,t}$:[4]

$$IN_{g,t} = \delta_{g,t}.Y_t \qquad \forall g \in G, \forall t \in T \qquad (6.1)$$

The zero-profit condition for each technology is given in equation (6.2). The complementary-slackness variable, the variable entering the complementary slackness condition (6.3) linked to equation (6.2), is output.

$$\sum_{g \in G} \delta_{g,t}.WIN_g - WY \geq 0 \qquad Y_t \geq 0 \qquad \forall\ t \in T \qquad (6.2)$$

$$\left(\sum_{g \in G} \delta_{g,t}.WIN_g - WY \right).Y_t = 0 \qquad \forall\ t \in T \qquad (6.3)$$

where WIN_g and WY represent prices of inputs and output respectively.

[3] This way of describing technologies would also allow for new intermediate inputs or a technology specific input (e.g., knowledge) to be part of the production function. This would not be possible if an industry had been calibrated using a single, smooth well-behaved neoclassical production technology.

[4] Since this technology specification only applies for dairy farming, for simplicity, subscript b (indicating industries) is omitted.

Equations (6.2) and (6.3) imply that technologies that are active ($Y_t > 0$) face zero-profits, while technologies that run a loss at equilibrium prices are inactive ($Y_t = 0$). In general, when a constraint is (not) binding[5], the complementary-slackness variable is positive (zero). For example policy changes, which alter relative prices, potentially trigger active (inactive) technologies to become inactive (active).

Böhringer (1998) also specifies a restricted technology specific factor $\overline{Q_t}$, which determines an upper bound on production for each technology. This capacity constraint is given in equation (6.4). The complementary-slackness condition linked to equation (6.4) is given in equation (6.5). The complementary-slackness variable is the shadow price (WQ_t) of the specific factor.

$$\delta_{Q_t}.Y_t - \overline{Q_t} \leq 0 \qquad WQ_t \geq 0 \qquad \forall \ t \in T \qquad (6.4)$$

$$\left(\delta_{Q_t}.Y_t - \overline{Q_t}\right).WQ_t = 0 \qquad \forall \ t \in T \qquad (6.5)$$

Hence, if the capacity constraint is (not) binding, the shadow price of the specific factor WQ_t is positive (zero). If the capacity constraint is binding, the shadow price WQ_t also enters equations (6.2) and (6.3)[6]. Due to this specification, a step-wise supply mapping emerges (see Böhringer, 1998)[7]. When relative prices change in favour of a latent technology (input prices decrease or output price increases), first equation (6.2) becomes binding and the latent technology becomes active. Production increases until equation (6.4) becomes binding and a shadow price for the capacity constraint occurs. An advantage of this specification is that a switch from one technology to another (specialisation) is not immediate since the rents

5 'Binding' implies that the strict equality condition holds.

6 Equations (6.2) and (6.3) then become:

$$\sum_{g \in G} \delta_{g,t}.WIN_g + WQ_t - WY \geq 0 \qquad Y_t \geq 0 \qquad \forall \ t \in T \qquad (6.2^*)$$

$$\left(\sum_{g \in G} \delta_{g,t}.WIN_g + WQ_t - WY\right).Y_t = 0 \qquad \forall \ t \in T \qquad (6.3^*)$$

7 Figure 1 in Böhringer (1998), that shows such a supply mapping graphically, may lead to two misunderstandings. First, by drawing in two-dimensional space (aggregate output versus price), the figure suggests that different technologies become active and reach full capacity successively. The simulations in this chapter but also in the paper by Böhringer show, however, that this might as well happen simultaneously. Secondly, the figure wrongly suggests a positive shadow price for a technology that has not yet reached full capacity (technology three).

for the capacity constraints serve as a kind of threshold[8]. In this chapter this approach is applied only in a sensitivity analysis where it is assumed that production by the new low-emission technology is restricted due to a technology specific factor ('new knowledge').

6.2.2 Restrictions on N emissions in agriculture

N emissions in agriculture are mainly due to manure production in dairy farming, pig farming and poultry farming and the use of fertiliser in all agricultural industries. N emissions that result from manure production are assumed to be related to output by the industry concerned. Hence, N emissions in agriculture are defined as:

$$N_{agr} = \sum_{t \in T} \psi_{N,t}^{Y_t} . Y_t + \sum_{b=2}^{6} \sum_{g \in G} \psi_{N,g,b}^{IN} . IN_{g,b} + \sum_{b=2}^{6} \psi_{N,b}^{Y_b} . Y_b \tag{6.6}$$

where ψ are emission coefficients expressed in kg N for output by Leontief technologies in dairy farming (Y_t), inputs in other agricultural industries ($IN_{g,b}$) and output in other agricultural industries (Y_b)[9]. In equation (6.7), it is assumed that total N emissions in agriculture (N_{agr}) will be restricted to the benchmark level $\overline{N}_{agr}$ by means of a system of tradeable N emission rights. The complementary-slackness condition linked to equation (6.7) is given in equation (6.8). The complementary-slackness variable is the shadow price (WN) of the emissions, or because of tradeability, the price of the N emission rights[10].

$$N_{agr} - \overline{N}_{agr} \le 0 \qquad\qquad WN \ge 0 \tag{6.7}$$

$$\left(N_{agr} - \overline{N}_{agr}\right).WN = 0 \tag{6.8}$$

[8] Böhringer (1998) creates such thresholds by assuming and calibrating a rent for capacity constraints in the benchmark already. This partly explains the fact that in his simulations five technologies in one industry can be active simultaneously.

[9] It is relevant whether emissions are linked to output or inputs. In the case of inputs, a reduction of emissions is less costly and hence the shadow price of emissions is lower, since substitution possibilities are greater (see also Chapter 5). A Leontief technology, however, does not allow for substitution and hence, it is indifferent whether emissions are related to input or output. Since in dairy farming a Leontief technology is assumed, N emissions of fertiliser are also linked to output.

[10] Hence, in this chapter *WN* is assumed to be the same over all commodities and agricultural industries.

Hence, if the N emission constraint is (not) binding, the shadow price of an N emission right WN is positive (zero). Because N emissions are related to inputs and output, WN enters the zero-profit condition (6.9) for the other agricultural industries[11]:

$$WY_b.Y_b = \sum_{g \in G} WIN_{g,b}.IN_{g,b} + WAPR_b.APR_b + \sum_{g \in G} WN.\psi^{IN}_{N,g,b}.IN_{g,b} + WN.\psi^{Y_b}_{N,b}.Y_b \quad \forall \; b \in B \qquad (6.9)$$

The shadow price WN also enters the zero profit condition (6.10) and complementary slackness condition (6.11) (with complementary-slackness variable Y_t) for each technology in dairy farming.

$$\sum_{g \in G} \delta_{g,t}.WIN_g + WN.\psi^{Y_t}_{N,t}.Y_t - WY \geq 0 \qquad Y_t \geq 0 \qquad \forall \; t \in T \qquad (6.10)$$

$$\left(\sum_{g \in G} \delta_{g,t}.WIN_g + WN.\psi^{Y_t}_{N,t}.Y_t - WY \right).Y_t = 0 \qquad \forall \; t \in T \qquad (6.11)$$

Equations (6.6) to (6.8), (6.10) and (6.11) fully describe the discrete technology switches in dairy farming. When the N emission constraint in agriculture (6.7) is binding and hence the shadow price of N emissions becomes positive (6.8), for active N-intensive technologies, equation (6.10) becomes non-binding and eventually these technologies become inactive. Due to a higher price for output, equation (6.10) becomes binding for latent N-extensive technologies and these technologies become active.

6.2.3 Technology description

To describe both the active and latent technologies in dairy farming, input-output vectors for each individual technology are necessary. For dairy farming two active technologies are defined: an N-intensive active technology (technology 1: dirty active) and a less N-intensive technology (technology 2: clean active). For this purpose the average input-output vectors for two groups of farms, with more or less than the average N-emissions per unit of output are

[11] In fact, equation (6.9) is a combination of equations (5.2) and (5.7) in Chapter 5 and replaces equations I.22, I.23 and I.24 for agricultural industries in the basic model (see Appendix I).

determined, using a stratified sample of specialised Dutch dairy farms that kept accounts on behalf of the Agricultural Economic Research Institute (LEI) farm accounting system (LEI, 1992). These input-output vectors are used as prior information to divide the input-output vector of dairy farming taken from the 1993 SAM in a cross-entropy procedure (Golan, et al., 1996). Appendix XIV provides a detailed representation of the distinguished technologies and the procedure that has been followed.

The inactive, new technology (technology 3: clean latent) is assumed to be an N-extensive technology. Results of a comparison between normal and N-extensive management of dairy farming at the 'Marke', a Dutch experimental farm, are used to describe the input vector of the third latent technology. Research at the 'Marke' showed that although the N extensive technology is feasible, due to more intensive use of non-N-intensive inputs (labour, capital and agricultural services), it would run at an economic loss at benchmark prices. Therefore, in the absence of an N emission restriction (zero shadow price for N) such a technology is not attractive to farmers compared to their currently applied technologies[12].

Table 6.1 *Summary of technologies in dairy farming*

	Inputs in values and as % shares of output (values in million 1993 guilders)						
	Use table Dairy farming		Technology 1 Dirty active		Technology 2 Clean active		Technology 3 Clean latent
Hired labour	193	1.7%	87	1.8%	106	1.7%	1.9%
Capital[a]	3107	27.8%	1396	29.4%	1711	26.7%	31.7%
Economic loss	0	0.0%	0	0.0%	0	0.0%	-0.3%
Cattle	1192	10.7%	563	11.8%	629	9.8%	11.8%
Arable products	323	2.9%	124	2.6%	199	3.1%	0.5%
Compound feed	2432	21.8%	1077	22.7%	1355	21.1%	22.4%
Fertiliser	316	2.8%	121	2.5%	195	3.0%	1.0%
Agricultural services	980	8.8%	376	7.9%	604	9.4%	9.6%
Other input	2624	23.5%	1009	21.2%	1615	25.2%	21.4%
Total	**11167**	**100.0%**	**4753**	**100.0%**	**6414**	**100.0%**	**100.0%**
N emissions/output	0.032		0.034		0.030		0.020

[a] Including land and self employed labour.

Table 6.1 summarises technologies 1 to 3, which are presented in detail in Appendix XIV. Of the two active technologies, technology 2 can be characterised as the more intensive technology: per unit of capital (incl. land) more fertiliser, agricultural services and other input are used. Moreover, the use of less livestock suggests that livestock is more productive.

[12] See Appendix XIV for a detailed representation of this technology. At the same level of output as the normal management system, the N-extensive management system uses 2 per cent more labour, 8% more capital, 22 per cent more agricultural services, 10 per cent less feed and 60 per cent less fertiliser leading to 40 per cent less N emissions (PR, 1998, table 9).

Evidence for the phenomenon that more intensive farms are also more N efficient is also found by Reinhard (1999, p. 95). The new (latent) technology is less intensive. Less fertiliser and compound feed is used while more factor input (labour and capital) and agricultural services are used. The difference in technology and farm management[13] leads to lower N emissions.

6.3 Policy simulations

The Dutch government fears that milk quota enlargement or abolition would lead to a strong growth in mineral production that would require additional environmental policy measures. Especially the growth of N emissions is unacceptable given the EU Nitrates Directive. In the base simulation, a milk quota[14] increase is modelled with total N emissions in agriculture restricted at the benchmark level[15].

Two sensitivity analyses are pursued. First, to show the effects of the restriction on total N emissions, the results of a quota increase in combination with three different N emission restrictions are compared: no restrictions on N emissions, N emissions restricted to the benchmark level (base simulation) and a 10 per cent reduction of total N emissions. The second sensitivity analysis concerns three alternative technology specifications of dairy farming. It compares the base simulation (Leontief technologies) with a CES specification of dairy farming (as in other chapters) and with a simulation in which output by the new Leontief technology is restricted. The latter simulation shows the effects of a specific factor linked to a new technology. The specific factor can be knowledge (human capital) needed to use and implement the new technology (technology 3). This knowledge is limited and therefore, given the Leontief production function, output of technology 3 is restricted to an arbitrarily assumed maximum of 5% of total output in dairy farming.

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13 Differences in farm management are, for example, an increase in own roughage production, more storage and transportation of manure and a longer stay of cows inside.

14 The supply quota is modelled as a strict equality, using a variable *ad valorem* tax rate that induces a level of output by dairy farming equal to the quota. The 'tax revenue' of this tax equals the quota rent (see Hertel and Tsigas, 1991) that is set equal to 1500 mln (1993) guilders (see Appendix XIV for a calculation).

15 Prices of milk and dairy products are endogenously determined in the model, however EU and world market prices of dairy products (milk is not traded) are exogenously fixed at the 1993 level. Therefore, under the quota enlargement simulations, EU and world market dairy prices are probably over-estimated. However, because (world market and EU) prices for dairy products are unknown the most simple assumption, namely constant prices, is adopted.

6.4 Results

This section graphically presents some of the results of a milk quota increase with total N emissions in agriculture restricted at the benchmark level. Results of the base simulation are also provided in tables in Section 6.5 where the results of sensitivity analyses are presented.

Figure 6.1 shows that an increase of milk quota leads, as quota rights become less scarce, to a lower value of milk quota. When the value of milk quota reaches zero (quota is no longer restrictive), the production of dairy farming has increased by 12.2 per cent (see third column of Table 6.2). Since N emissions in agriculture are restricted at the benchmark level, a higher production in dairy farming will lead to a positive and increasing shadow price of N emissions. At the point where milk quota is no longer restrictive, the shadow price is 0.99 guilders (1993) per kg N (see third column of Table 6.2). The symmetry between the two curves in Figure 6.1 shows the mutual dependency between the value of milk quota and the shadow price of N emissions. Clearly, while the quota on dairy production becomes less restrictive, the constraint on N emissions in agriculture becomes more restrictive.

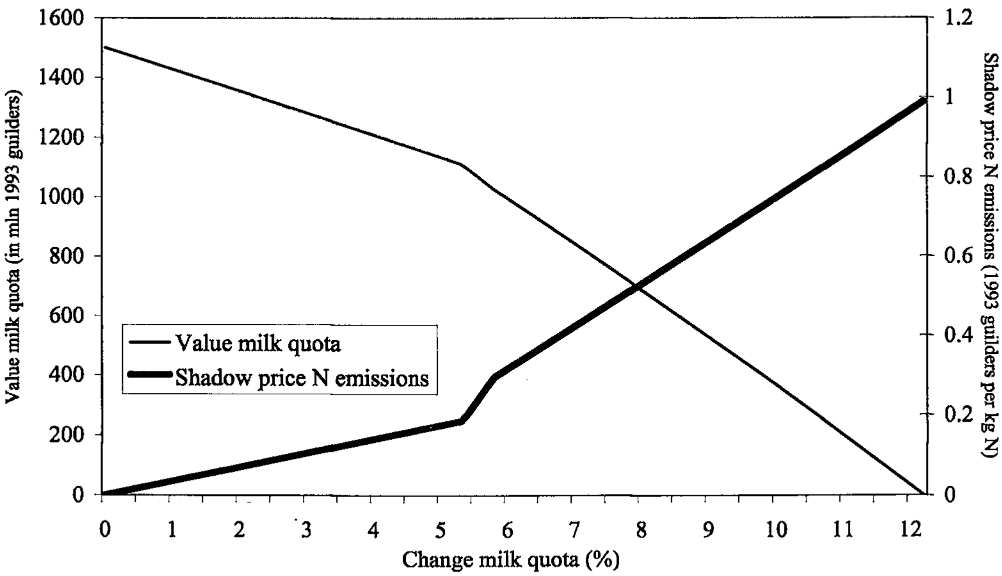

Figure 6.1 *Effects milk quota increase for value milk quota and shadow price N emissions*

The kinks in Figure 6.1 are due to technology switches in dairy farming, which is shown in Figure 6.2. Initially, technology 2 (clean active) fully accounts for the increase of production in dairy farming. This is the result of two effects that work in the same direction. First, since factor inputs are imperfectly mobile between industries (see Chapter 2), the technology that is less factor intensive (technology 2) has an advantage (see Table 6.1). Second, due to the increase in the shadow price of N emissions, output is shifted from technology 1 to the cleaner technology 2. At a milk quota increase of 5.4 per cent, technology 1 becomes inactive, and all output is produced by technology 2. At this point, there is no longer substitution between technology 1 and technology 2, which causes the shadow price of N emissions to rise faster as dairy production increases. At a milk quota increase of 5.8 per cent the increase in the shadow price of N emissions slows down. At this point the shadow price of N emissions is high enough to trigger clean technology 3. Part of production by technology 2 is now shifted to technology 3. This takes place although technology 3 uses more imperfectly mobile factor inputs (see Table 6.1)[16]. At the point where milk quota is no longer restrictive, 91 per cent of dairy production is produced by technology 2 and 9 per cent by technology 3 (see third column of Table 6.2).

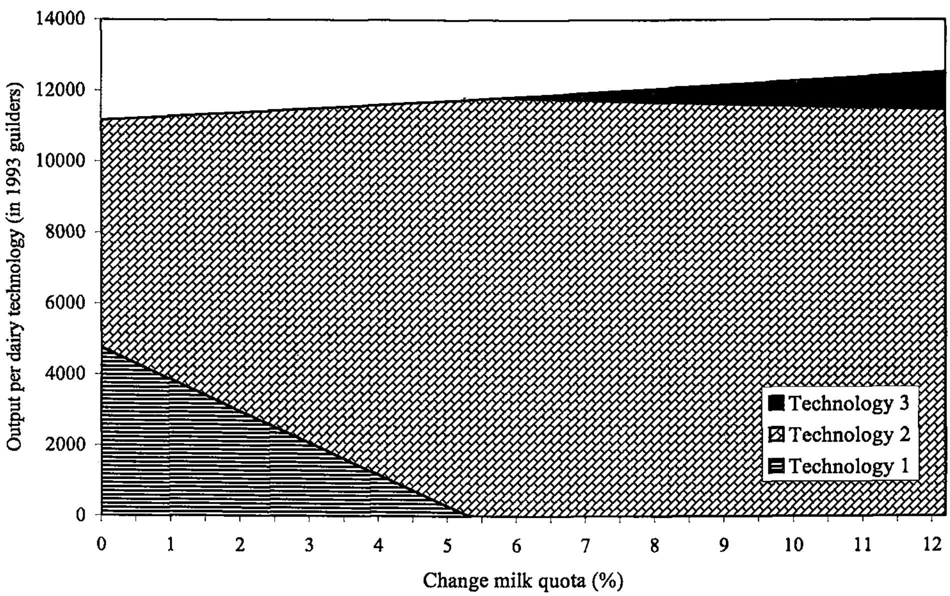

Figure 6.2 *Effects milk quota increase for output different dairy technologies*

[16] Since factor inputs are imperfectly mobile, prices of factor inputs tend to increase faster than prices of intermediate inputs. Additional sensitivity analysis (not presented here) indeed shows that with increased factor mobility, the price increase of factor inputs is lower. In that case, technology 1 stays active longer while technology 3 becomes active earlier.

Figure 6.3 shows that as the shadow price of N emissions increases, production by pig and poultry farming decreases due to an increase of output and emissions in dairy farming, given that N emissions in agriculture are restricted to the benchmark level. The negative effect on income is partly offset by a decrease in feed prices (-1.4 per cent). At the point where milk quota is no longer restrictive, production by pig farming and poultry farming decreases by 7.5 per cent and 3.2 per cent respectively (see Table 6.2). Pig farming is most sensitive to an increase in milk quota when total N emissions are restricted since production is N-intensive while the reduced output hardly generates a price increase due to the homogeneity assumption for trade in pigs.

Results further show that at the point where milk quota is no longer restrictive, the higher production by dairy farming increases the net export of dairy products and beef (respectively 21.8 per cent and 14.3 per cent, see Table 6.2). Moreover, welfare increases (242 mln 1993 guilders) and the exchange rate decreases (-0.21 per cent appreciation of the guilder, see Table 6.2) which reflects the improved international competitiveness.

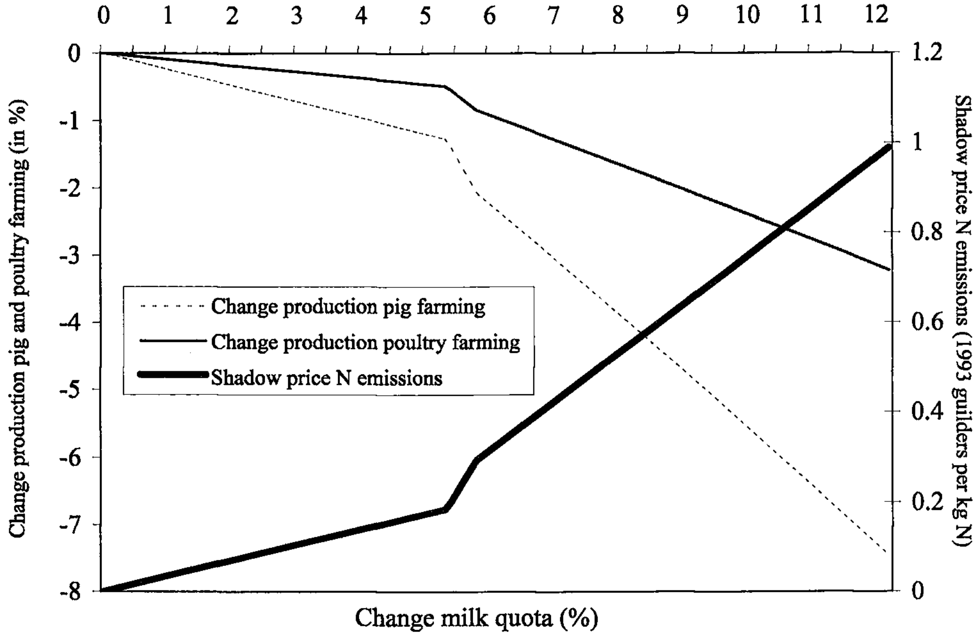

Figure 6.3 *Effects milk quota increase for output other livestock industries*

6.5 Sensitivity analysis

This section contains two sensitivity analyses. The first sensitivity analysis compares the effects of milk quota abolition at three different N emission restrictions: no restrictions on N emissions, N emissions restricted to the benchmark level (base simulation) and a 10 per cent reduction on total N emissions. The second sensitivity analysis concerns quota abolition at three alternative technology specifications of dairy farming: dairy farming represented by a single CES technology (as in other chapters), the multiple Leontief technology of the base simulation, and the multiple Leontief technology where output by the new Leontief technology is restricted.

6.5.1 Alternative assumptions on the N emission restriction

Results show that in the case of a milk quota increase without N restrictions, full specialisation towards the second technology takes place while the first technology becomes inactive. This is because the second technology uses less labour and capital per unit of output (see Table 6.1). However, since there are no restrictions on total emissions, technology 1 stays active longer then in the base simulation (technology 1 becomes inactive at a milk quota increase of 6.9 per cent compared to 5.4 per cent in the base simulation). Technology 3 never becomes active since it uses more labour and capital per unit of output then technology 2 (see Table 6.1). Production of dairy farming is larger in the point where milk quota is no longer restrictive than in the base simulation (16.2 per cent increase compared to 12.2 per cent increase in the base simulation, see Table 6.2) because there is no negative effect of a restriction on N emissions on dairy production. The larger increase in dairy production also decreases the exchange rate and increases welfare more (-0.49 per cent and 485 mln 1993 guilders respectively, see Table 6.2).

In the welfare increase the negative utility of an increase in national N emissions (4.1 per cent, see Table 6.2) is not incorporated. The negative welfare from this emission increase should be smaller than the extra welfare increase compared to the base simulation (485-242=243 mln guilders) in the case quota would be abolished. Pig and poultry production is not negatively affected by the N restriction in this simulation. However, the higher feed prices, due to a larger demand for feed by the dairy industry, and the larger exchange rate decrease do lead to small negative effects on production and income in both industries.

Table 6.2 *Effects on Dutch economy of milk quota abolition under different restrictions on N emissions in agriculture (in % changes from benchmark)*

Variable[a]	No restriction N emissions	Base simulation	10% reduction N emissions
Output			
Dairy farming (11167)	16.2	12.2	7.7
Share technology 1 (0.43)	0.00	0.00	0.00
Share technology 2 (0.57)	1.00	0.91	0.56
Share technology 3 (0.00)	0.00	0.09	0.44
Pig farming (5646)	-0.4	-7.5	-10.1
Poultry farming (2415)	-0.2	-3.2	-4.4
Arable farming (2941)	-1.1	-2.0	-2.2
Compound feed industry (9489)	3.9	-1.2	-3.4
Fertiliser industry (1714)	3.0	1.4	-3.4
Prices			
Labour in dairy farming	23.7	17.9	18.6
Capital in dairy farming	20.6	16.6	20.9
Compound feed	-0.7	-1.4	-1.5
Fertiliser	4.1	2.1	-3.6
Agricultural services	7.1	5.4	4.1
Input fertiliser			
Dairy farming (249)	24.8	13.7	-18.0
Arable farming (136)	-2.2	-3.7	-3.3
Net export			
Dairy products (4851)	27.4	21.8	14.5
Beef (3053)	18.7	14.3	7.8
Pigs (746)	2.7	-43.9	-62.6
Pig meat (3111)	-1.7	-1.3	-0.7
Poultry meat (1327)	-0.6	-3.4	-4.3
Fertiliser (862)	-2.3	-1.2	0.4
N emissions			
Dairy farming (355)	11.3	4.4	-12.1
Pig farming (159)	-0.4	-7.5	-10.1
Poultry farming (60)	-0.2	-3.2	-4.4
Arable farming (39)	-2.2	-3.7	-3.3
Horticulture under glass (8)	-1.2	-0.9	-0.2
Other horticulture (7)	-1.3	-1.1	-0.2
Agriculture (628)	6.1	0.0	-10.0
TOTAL (976)	4.1	0.1	-6.4
Miscellaneous			
Shadow price N emissions[b]	0	0.99	1.35
Exchange rate[c]	-0.49	-0.21	-0.01
Welfare[d]	485	242	22

[a] Base-year quantities, in mln 1993 guilders and mln kg N emissions, between parentheses.
[b] In 1993 guilders per kg N.
[c] Changes in 1993 guilders per dollar.
[d] In mln 1993 guilders.

A 10 per cent reduction of total N emissions compared to the benchmark level makes technology 1 immediate inactive and technology 3 immediate active. A milk quota increase leads then to a continuous substitution of output produced by technology 3 for output produced by technology 2, although technology 3 uses more factor inputs per unit of output. The cleaner production in dairy farming is also shown by a reduction of N emissions in dairy farming of 12.1 per cent.

As quota increases, the shadow price of N emission rights increases faster than in the base simulation. This makes milk quota non-restrictive faster (7.7 per cent milk quota increase compared to 12.2 per cent in the base simulation). At that point there is a welfare increase of 22 mln guilders (see Table 6.2). Therefore the welfare gain from making milk quota no longer restrictive is larger than the welfare loss of reducing total N emissions with 10 per cent. Production in pig and poultry farming decreases more than in the base simulation. This has a negative effect on the exports of both industries. Therefore the exchange rate appreciates with only –0.01 per cent.

6.5.2 Restrictions on technologies

It could be the case that new technologies cannot be used by all farms since certain knowledge or 'human capital' is limited available. Given a Leontief technology, the presence of such a technology specific fixed factor puts a maximum on the output level that can be produced with the technology. It is assumed that the output by technology 3 cannot be larger than 5 per cent of total output in dairy farming. The presence of a technology specific fixed factor is compared with the base simulation. In addition, the base simulation is compared with a CES technology specification in dairy farming[17].

The third column in Table 6.3 shows that the 5 per cent output restriction on technology three leads to a smaller increase in the production of dairy farming and a lower production of pig and poultry farming at the point where milk quota is no longer restrictive. If the output maximum is reached for technology 3, lower N emissions can only be achieved by reducing production. These lower production levels lead to smaller exports and a smaller decrease of the exchange rate. The large reduction in export of pigs (homogeneity assumption) avoids a large decrease of pig meat exports. Because the specific factor in technology 3 is restrictive, a shadow price for this capacity constraint occurs. Although the abolition of milk quota removes a restriction in the economy, the N emission restriction and the restriction on

[17] This specification has been applied in the other chapters. In this specification, approximately 40% of the N emissions is related to the input of fertiliser and 60% to output.

technology 3 partly take over this role. This is represented by the higher shadow price of N emissions of 1.22 guilders per kg and lower welfare increase of 202 million 1993 guilders.

Table 6.3 *Effects on Dutch economy of milk quota abolition under different technology restrictions with N emissions in agriculture restricted to the benchmark (% change from benchmark)*

Variable[a]	Base simulation	Technology 3 ≤ 5% output dairy farming	CES technology dairy farming
Output			
Dairy farming (11167)	12.2	11.9	6.7
Share technology 1 (0.43)	0.00	0.00	-
Share technology 2 (0.57)	0.91	0.95	-
Share technology 3 (0.00)	0.09	0.05	-
Pig farming (5646)	-7.5	-9.2	-14.6
Poultry farming (2415)	-3.2	-3.9	-7.0
Arable farming (2941)	-2.0	-2.3	-2.2
Compound feed industry (9489)	-1.2	-2.4	-5.1
Fertiliser industry (1714)	1.4	1.9	1.1
Prices			
Labour in dairy farming	17.9	16.1	9.8
Capital in dairy farming	16.6	14.7	8.7
Compound feed	-1.4	-1.6	-1.5
Fertiliser	2.1	2.5	1.2
Agricultural services	5.4	5.2	1.6
Input fertiliser			
Dairy farming (249)	13.7	16.2	8.4
Arable farming (136)	-3.7	-4.2	-4.1
Net export			
Dairy products (4851)	21.8	21.5	13.2
Beef (3053)	14.3	14.2	6.3
Pigs (746)	-43.9	-54.9	-81.2
Pig meat (3111)	-1.3	-1.2	-0.5
Poultry meat (1327)	-3.4	-4.0	-5.4
Fertiliser (862)	-1.2	-1.2	-0.2
N emissions			
Dairy farming (355)	4.4	5.3	7.2
Pig farming (159)	-7.5	-9.2	13.0
Poultry farming (60)	-3.2	-3.9	-5.6
Arable farming (39)	-3.7	-4.2	-4.1
Horticulture under glass (8)	-0.9	-0.9	0.5
Other horticulture (7)	-1.1	-1.2	-0.8
Agriculture (628)	0.0	0.0	0.0
TOTAL (976)	0.1	0.1	0.0
Miscellaneous			
Shadow price N emissions[b]	0.99	1.22	1.68
Exchange rate[c]	-0.21	-0.16	0.12
Welfare[d]	242	202	-71
Technology rent technology 3[e]	-	2.2	-

[a,b,c,d] See Table 6.2.
[e] In mln 1993 guilders.

The fourth column in Table 6.3 shows that assuming the CES technology is more restrictive than assuming multiple Leontief technologies (with or without restriction). With the CES technology it is less easy to reduce N emissions, which leads to a higher shadow price for N emissions of 1.68 guilders per kg and a welfare reduction. Output of dairy farming only increases by 6.7 per cent while output in other agricultural industries is reduced more. The lower output in agriculture leads to smaller exports and an increase of the exchange rate (depreciation of the guilder).

6.6 Summary and conclusions

The purpose of this chapter is to analyse the effects of an increase in milk quota in the Netherlands when nitrogen (N) emissions are restricted, using an AGE model written in mixed-complementarity format (AGE-MC model). The AGE-MC model combines the strengths of AGE models and mathematical programming models, which enables economy-wide policy analyses while technology switches are allowed. Contrary to most other AGE models where each industry is represented by a single smooth well-behaved neoclassical production technology, in this chapter dairy farming is represented by a series of different technologies, where each technology is characterised by a different emission-input-output mix. The advantage of this approach over the single technology approach is that new, low-emission technologies can be taken into account. Consequently, technology switches make it feasible to reduce emissions without necessarily reducing output, which would be the case if emissions had been related to output in a well-behaved neoclassical production technology. A disadvantage of the proposed approach is that a Leontief specification is required to allow for zero activity. This specification underestimates the substitution possibilities within each technology. Ideally, one could approximate a continuous production frontier by specifying an infinite number of Leontief technologies. Due to data-limitations, the number of technologies in this chapter is limited to three. Further efforts in this direction might prove fruitful in future research.

Several other aspects also deserve further attention in future research. The treatment of existing quota rents (milk quota) in the benchmark and the determination of its value as part of value added needs further attention. Further, attempts could be made to closer approximate Dutch mineral policy, in which N emissions per hectare land are restricted and not total N emissions as such. By linking the N emission restriction to land, policy simulations would generate the effect of mineral policies on land prices. In addition, the relationship between livestock production and arable farming would be more pronounced.

The results in this chapter show that a welfare gain can be reached by increasing milk quota while keeping N emissions at the same level. Under such a policy change inactive N-extensive technologies in dairy farming become active and (partly) replace N-intensive technologies. Moreover, output in other agricultural industries decreases. Given these results, the Dutch government should not fear an increase in milk quota. An important task for the government, however, could be to stimulate the development of new low-emission technologies in agriculture, the introduction of which can partly offset the potential increase in N emissions.

The simulations in this chapter have shown that the results are sensitive to technology specification in dairy farming. Especially latent technologies are difficult to specify because of a lack of information. However, if this information is available, the AGE-MC approach proves to be a useful tool for policy analysis in cases where technology switches can be expected as a result of policy changes.

CHAPTER 7

DISCUSSION AND CONCLUSIONS

7.1 Introduction

This final chapter discusses the research in this thesis and draws conclusions. In Section 7.2, methodological and model issues are discussed. Section 7.3 gives feedback on the objectives of the thesis, summarises the simulation results and derives policy implications. Finally, some suggestions for future research are given in Section 7.4.

7.2 Methodological and model issues

The basic tool used in this thesis is a static, single-country applied general equilibrium (AGE) model for the Dutch economy. Without being exhaustive, some methodological and model issues that are relevant in the light of the simulations in this thesis are dealt with in this section. Specific model assumptions were already discussed in Chapter 2.

AGE modelling and other approaches

The analyses in this thesis have shown that an AGE model is an appropriate tool for analysing the economy-wide environmental and economic effects of environmental and agricultural policies and the interactions between these policies, in the Netherlands. Alternatives such as input-output analyses (Harthoorn and Wossink, 1987; Peerlings and Komen, 1998) or partial analyses are rather restrictive for various reasons. Input-output analysis assumes fixed input-output coefficients, perfectly elastic factor supplies, and exogenously determined final demands. The simulations in this thesis have shown that these assumptions may be too restrictive if large policy changes are analysed or when substitution possibilities are important. Partial models analyse just a single part of the economy, assuming fixed agricultural input and output prices while linkages with the rest of the economy are often ignored. AGE analysis, on the other hand, does not suffer from these restrictions and is therefore very useful in tracing and measuring inter-industry linkages between agricultural and non-agricultural sectors. Moreover, because AGE analysis encompasses the whole economy, there will be no 'leakage' during welfare analyses. Furthermore, the closed system of the SAM offers not only a theoretical but also an accounting consistency check, available from general equilibrium theory (Walras' Law), that is not available to partial equilibrium modellers (Hertel, 1990 and 1992). Finally, when substantial policy changes affect a number of sectors simultaneously, empirical modelling shows that partial equilibrium estimates are not likely to be robust (see de Melo and Robinson, 1981).

Calibration year and aggregation level

Although the model as applied in this thesis is calibrated on data of 1990 (Chapters 3 and 4) or 1993 (Chapters 5 and 6), it should not be viewed as out of date. Unless the structure of expenditure shares or factor shares has significantly changed, one may view the model as a representation of the present economy.

The simulations in this thesis have shown that the aggregation level is important for several reasons. First, since the focus of most policy simulations in this thesis is on agriculture, a sufficient level of disaggregation should be applied to be able to identify individual agricultural industries and commodities. If a policy is typical for one or a few agricultural industries (e.g., restricting intensive livestock farming, Chapter 3), simulation results are not very clear when such industries are part of a larger industry. For example, the reduction of the manure problem might cause horticulture under glass to reduce its production if agriculture had not been disaggregated in the model[1]. Second, a high level of disaggregation takes into account that industries and commodities are potentially heterogeneous with respect to policy variables (see also Just et al., 1991). This prevents overestimation of policy effects on those industries for which the policy variable is not relevant. Finally, a sufficient level of disaggregation enables an adequate linking of emissions to economic variables. The simulations in Chapter 5 have shown that such linking is highly relevant since outcomes depend on whether emissions are linked to inputs, aggregate output, consumer goods or aggregate consumption. Moreover, the heterogeneity among industries and commodities with respect to emission coefficients shows the potential benefits of a tradeable emission permit system over a non-tradeable permit system.

Model applicability

The range of simulations for which the AGE model can be used is limited. Each policy simulation involves different policy variables and is therefore biased to particular parts of the

[1] For example, Brockmeier et al. (1993) very likely overestimated the economy-wide effects of reduced pesticide application for Germany, due to an insufficient level of detail in the agricultural sectors.

economy. This could necessitate additional disaggregation, model specifications and data work. The pitfall is that once an AGE model is developed, it becomes more complicated after each policy simulation. Such a complicated model might cause solution problems. Moreover, the driving factors behind the model results are more difficult to trace. In this thesis the problem is partly circumvented by describing a basic version of the model in Chapter 2 that forms the basis for the modifications that were made in the following chapters.

Trade

It should be noticed that the way international trade is modelled limits the possibility for policy simulations related to trade liberalisation or reform of the Common Agricultural Policy (CAP) in the European Union (EU). The small country assumption implies that the model is feasible only for policies from which no change in world market prices can be expected, unless there is a priori information on changes in world market prices, for example obtained by a separate trade model (Komen, 1995). Moreover, an adequate treatment of the CAP reform requires that the international trade is separated into trade with the EU and the rest of the world while additional model specifications and data are required to model the CAP instruments (Gohin et al., 1998) and budgetary flows between the Netherlands and the EU.

Technology specification

In most AGE models, each industry is represented by a smooth well-behaved neoclassical production technology that is calibrated on the original data set using exogenously specified elasticities. A limitation of this approach is that new technologies are not taken into account, since they are not part of the current data set. The latter might be the case when policy changes trigger new technologies (e.g., lower emissions, less energy intensive production etc.) or abatement activities (see Nestor and Pasurka, 1995). In this thesis, these limitations are also in force for the policy simulations in Chapters 3 to 5 while in Chapter 6 technology switches are explicitly incorporated. It should be noticed, however, that this has only been applied for dairy farming. Application of technology switches throughout the whole model requires data to describe all the alternative technologies, which are often not available (see also Section 7.4 on future research).

7.3 Research goal, simulation results and policy implications

The main objective of this thesis, as described in Chapter 1, was to determine the economy-wide environmental and economic effects of agricultural and environmental policies and the interactions between these policies, in the Netherlands. Some of the most relevant policy simulations are dealt with in this thesis: (1) the manure policy; (2) the small-user energy tax; (3) the reduction of emissions causing eutrophication, the greenhouse effect, acidification and waste accumulation; and (4) the increase of milk quota under a nitrogen restriction. The aim was to quantify these policy effects, providing insight into the nature of the different environmental problems, the linkages between the economy and the environment, and the economic consequences of government intervention.

This section assesses the contribution of the policy simulations to the research goal, recapitulates the main results and derives policy implications. The results of the policy simulations are compared to the benchmark equilibrium. For Chapters 3 and 4, the benchmark year is 1990; for Chapters 5 and 6, the benchmark year is 1993. Discussion of the specific policy simulation results is found in the respective chapters.

Restricting intensive livestock production

Chapter 3 quantifies the effects on the Dutch economy of different reductions in intensive livestock production necessary to achieve environmentally acceptable phosphate losses. The simulations give a good insight into the economic effects of a stricter mineral policy. It is shown that the introduction of an environmental policy that is specific for agriculture entails economy wide effects, revealing the linkages that exist between agriculture and the rest of the economy.

A decrease in livestock production to achieve a phosphate loss of 30 kg/ha (policy goal in 2002) will decrease income from pig and poultry farming by 2.6 and 1.0 per cent, respectively. If pig production alone is reduced, the income from pig farming will decrease by 4.8 per cent. This is under the assumption that livestock farmers do not incur manure transportation costs and pay no levies. However, as this is unrealistic, the effects on income are underestimated. Nevertheless, the fact that the perfect homogeneity assumption in pig trade is used tends to overestimate the negative effects on income. The lower production in pig and poultry farming affects the production and income of the compound feed, pig and poultry meat industries more seriously than the livestock industries because of the absence of quota rents as part of income. The effects on trade are that net exports of livestock and net imports of feedstuffs decrease. Moreover, in all cases, the exchange rate appreciates, which indicates that the trade position of the Netherlands would deteriorate because of the livestock reduction. In the case of a permitted phosphate loss of 30 kg/ha when only pig production is reduced, welfare decreases by 800 mln. 1990 guilders, which is only 0.15 per cent of national income. This welfare reduction would be offset by environmental improvements that are not included in the welfare measure.

The results of the policy simulation in Chapter 3 form the background to discussions on the advantages and disadvantages of reducing livestock production in Dutch agriculture and on the design of policies in other countries that deal with the same environmental problems. They show the linkages that are present between livestock production and the rest of the economy. An important policy implication is the fact that industries related to the livestock industries (compound feed, pig and poultry meat industries) suffer a greater fall in income than the livestock industries themselves. This result is mainly due to the compensating effect of the quota rents for current farmers. However, the value of this quota (production rights) forms an entry barrier and has a negative effect on the structure of intensive livestock farming.

Introduction of an energy tax

In Chapter 4, the environmental and economic effects of the introduction of a unilateral energy tax are analysed. The effects of a small-user energy tax and a general energy tax are compared while taking into account different tax recycling mechanisms (e.g., reducing taxes on labour). Such an energy tax might improve the environment (first dividend) but also reduce the distortionary costs of the tax system (second dividend). The introduction of an energy tax is a typical general environmental policy that might potentially affect agriculture, in particular horticulture under glass that is both energy and labour intensive.

The simulations in Chapter 3 show that the small-user energy tax (25 per cent for gas, 15 per cent for electricity, 25 per cent for coal and 20 per cent for other fuels for heating) causes a CO_2 reduction of 3.5 per cent while total emissions of greenhouse gases are reduced by 3.1 per cent. By recycling revenues of the small-user energy tax, employment increases by 0.10 per cent and existing tax distortions decrease (second best welfare improvements), resulting in a higher national welfare of 0.06 per cent. When the tax base is broadened to all energy users and exemptions are ignored, welfare decreases by 0.02 per cent and the exchange rate increases by 0.25 per cent. This illustrates that in the case of the general energy tax, international competitiveness of the large energy-using industries deteriorates. Within agriculture, horticulture under glass is the most affected industry although the effects are small. Sensitivity analyses of the results show that the positive welfare effects of a small-user energy tax only apply at low tax rates. At higher tax rates, the negative distortionary effects of the introduction of a small-user energy tax dominate the positive effect of redistributing existing distortions from labour to capital. At a CO_2 reduction higher than 25 per cent, welfare costs of a small-user energy tax even become higher than welfare costs of a general energy tax, which is due to a broader tax base of the general tax.

The CO_2 reduction obtained is less than the target of 3-5 per cent reduction in 1989-1990 CO_2 levels by 2000, established by the Dutch government, because economic growth is not considered in the simulations. The results are hardly comparable with other studies focusing on the effects of an energy tax for the Netherlands, which is due to different modelling assumptions and policy simulations. The results show that it is rational to exempt large users from an energy tax to avoid loss of international competitiveness. Only at high reduction levels might it be more efficient to tax large energy users as well, since then an increased tax base proves to be less distorting. Under the restrictions of the model used, a second dividend can be achieved by the introduction of a small-user energy tax. At low tax rates, a welfare improvement is even possible when the revenues of a small-user energy tax are recycled in a lump sum fashion. These typical second-best results occur due to an inefficient initial distribution of the tax burden. From a policy perspective the question remains, however, whether introducing an energy tax is the appropriate tool to reduce distortions caused by other taxes.

Multiple environmental policy goals

Chapter 5 analysed the environmental and economic effects of restricting greenhouse gases, acidification, eutrophication and waste accumulation by means of a system of emission permits. Emissions are linked to inputs, aggregate output, consumer goods and aggregate consumption at a very detailed level. Attention is paid to the different effects of reducing single environmental indicators, the interaction effects of reducing different environmental indicators simultaneously and the tradeability of emission permits. Although policy simulations in this chapter are fictitious general environmental policies that affect agriculture (10% reduction of environmental indicators), they contribute to the aim of this thesis. The simulations provide insight into the nature of the different environmental problems, the linkages between the economy and the environment and the potential economic consequences of government intervention in the Netherlands. Moreover, possible interaction between environmental policies is revealed.

The results in this chapter show large differences in welfare losses as result of restricting different environmental indicators, which can be explained by the extent to which inputs, aggregate output, consumer goods and aggregate consumption can be substituted. In the case of waste emissions and to a lesser extent of eutrophication, where emissions are related to aggregate output and aggregate consumption, substitution is hardly possible and a reduction of emissions will therefore be very costly. In the case of acidification and greenhouse gas emissions, however, a reduction can mainly be achieved by substitution of zero or low emission commodities for high emission commodities, which entails relatively low costs. Moreover, in the latter case, emissions are widely distributed over all industries and consumers, which, especially in the case of tradeable emission permits, offers scope for an efficient allocation of the emission reduction. These results emphasise the need for a very detailed emission matrix at a disaggregated level as applied in this chapter. The simulations also show that environmental policies might interact, when different environmental indicators are related to the same economic variables. When two or more environmental policy goals are set simultaneously, individual restrictions are less restrictive and hence shadow prices of restrictions will be lower. In addition, the welfare loss of an additional environmental restriction is relatively small. Finally, the simulations in this chapter show the potential benefits of a system of tradeable permits over a system of non-tradeable permits. When permits are tradeable, permit prices for 1 kg CO_2 equivalent (greenhouse effects), 1 mole H^+ (acidification), 1 kg N equivalent (eutrophication) and 1 kg waste (waste accumulation) at 10 per cent reduction of the concerning emissions are 0.04, 0.18, 1.52 and 3.37 guilders (1993) respectively. These are lower than the average shadow prices in the case of non-tradeability (0.13, 1.03, 21.43 and 9.41 respectively). The difference in welfare loss between non-tradeable and tradeable permits is largest in the case of eutrophication (5476 vs. 1060 million guilders), which is due to the large differences in eutrophication emission coefficients between agents.

From a policy perspective, the simulations in this chapter give insight into the potential effects of achieving different environmental policy goals. Since both direct and indirect effects are taken into account in the AGE framework used, the links between environmental problems and economic activity are placed in a broad perspective. The simulation results show that the economic impact of an emission reduction depends largely on substitution possibilities. Since these possibilities are often limited, especially when emissions are related to output, there is a potential pay-off to increasing the search for low-emission technologie·

Moreover, confirming the results obtained in earlier studies, the gain of a tradeable emission permit system over a non-tradeable system shows the need for a market-based approach when emissions are to be reduced. Finally, since restrictions on different environmental indicators might interact, there is clearly scope for policy co-ordination when multiple environmental policy goals are to be met.

Trade-off between environmental and agricultural policies

Chapter 6 analyses the effects of an increase in milk quota in the Netherlands when nitrogen (N) emissions in agriculture are restricted. This policy simulation is the only example in this thesis of an agricultural policy change that entails environmental effects. In addition, it clearly shows the linkages that exist between agricultural industries. The contribution of this chapter is also of a methodological nature, since the AGE model is written in mixed-complementarity format (AGE-MC model). The AGE-MC model combines the strengths of AGE models and mathematical programming models. Contrary to the other chapters, where technology in each industry is fixed, this format enables economy-wide policy analyses while technology switches are allowed.

The results show that as milk quota rights become less scarce, the value of milk quota reaches zero. Since N emissions in agriculture are restricted, a higher production in dairy farming will lead to a positive and increasing shadow price of N emissions. At the point where milk quota is no longer restrictive, the shadow price is 0.99 guilders (1993) per kg N. The mutual dependency between the shadow prices of milk quota and N emissions shows that while the quota on dairy production becomes less restrictive, the constraint on N emissions in agriculture becomes more restrictive. Still, a welfare gain can be reached by increasing milk quota while keeping N emissions at the same level. Under such a policy change, inactive N-extensive technologies in dairy farming become active and (partly) replace N-intensive technologies, due to an increase in the shadow price of N emissions. For the same reason, output in other agricultural industries decreases, which shows that policy measures taken in one industry may indirectly (through the market for N emission permits) affect other industries.

The simulations in Chapter 6 have shown that the results are sensitive to the specification of technology in dairy farming. The AGE-MC approach, using multiple Leontief technologies, seems to be more flexible than using a single CES technology. If the AGE-MC approach is adopted, results depend on the specification of the alternative (both existing and latent) technologies. Especially latent technologies are difficult to specify because of a lack of information. However, if this information is available the AGE-MC approach proves to be a useful tool for policy analysis in cases where technology switches can be expected as a result of policy changes.

From a welfare perspective, the Dutch government should not fear an increase in milk quota. It is important to note, however, the increasing shadow price of N emissions, which indicates an increasing pressure on the 'market' for environmentally harmful N emissions, indirectly affecting the other agricultural industries. Given the results obtained, an important task for the government could be to stimulate the development of new low-emission technologies in agriculture, the introduction of which can partly offset the potential increase in N emissions.

7.4 General remarks and future research

General remarks

The policy simulations in this thesis are used to reveal the economy-wide environmental and economic effects of agricultural and environmental policies and the interactions between these policies, in the Netherlands. Although the most important policy issues are dealt with, the policy simulations in this thesis do not cover the total field of potential policy issues to be analysed with the AGE model. Another environmental policy in the Netherlands affecting agriculture is the pesticides policy, and an example of agricultural policies that potentially entail environmental effects is the Agenda 2000 reform of the CAP in the EU (Hanley and Oglethorpe, 1999).

The simulations give a good insight into the effects of policy changes. However, the results should be interpreted with care for several reasons. First, since real policies are usually too complicated to be tackled in an economic model, there is always the chance of a certain degree of policy mis-specification. For example, the presence of energy covenants (in horticulture) or seasonal manure application norms are difficult to deal with in an AGE model. Second, it is worth mentioning that policies could be subject to large changes during the time period in which applied policy research can be completed. Policies that first look premature, may eventually be implemented and finally turn out to be replaced or supplemented by other policies[2]. The changing policy environment is also reflected by the different policy simulations in this thesis[3]. Finally, the results are conditional on the model and data characteristics; for example, functional forms, specification of agents and commodities, and the static nature of the model. Therefore, for some of the critical assumptions (factor mobility, trade, and labour supply) sensitivity analyses were performed.

Future research

Considering the remarks and conclusions in the preceding chapters, several suggestions for future research can be made. In order to get more insight into the interaction between agricultural and environmental policies, there are still some policy simulations left to deal with, like other environmental policies (pesticides policy) and policy simulations related to CAP reform.

A drawback of AGE models is that they are not econometrically estimated. Although full econometric estimation is impossible (Gunning and Keyzer, 1995) it is possible to estimate components of an AGE model like the input demand system, export supply, import demand or household demand (see Kemfert, 1998, on substitution elasticities of nested CES production functions and Shiells and Reinert, 1993, and Shiells et al., 1986, on trade substitution elasticities). Maximum entropy econometrics, an estimation techniques for small samples (Golan, et al. 1996) in combination with frequently published SAMs could be used in the future to (partially) estimate AGE models.

An interesting area of research might be to incorporate micro-econometric simulation models[4] into AGE models. Many issues in environmental economics require both detailed insight at the level of the decision-making units (individual farms) and the consequences of such decisions for the environment and the economy as a whole (Oglethorpe and Sanderson,

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2 In fact this is the case for the policy described in Chapter 3. At the time the policy simulations were performed (1996), a restriction of intensive livestock production was politically not feasible. In 1998, however, this policy has actually been introduced for pig farming with a system of pig production rights, aiming at reduction levels similar to the policy simulations in Chapter 3. In 1999, the reduction of these production rights has partly been cancelled by a lawsuit against the Dutch government and was supplemented by a system of manure sales contracts. In spring 2000, again supplementary policy has been introduced. The government stimulates pig farmers to quit by buying production rights, while in specific parts of the Netherlands farmers receive a subsidy to dismantle their stables.

3 For example, the mineral or manure problem has been dealt with in three different ways in this thesis. In Chapter 3 the focus was on phosphate and livestock numbers and in Chapter 6 the focus was on nitrogen, while in Chapter 5 eutrophication as a whole is considered.

4 Micro-econometric simulation models are defined here as econometric models of firms or farms, based on micro-economic theory, that are used to simulate the effects of policies on farm-level and in some cases sector level (see Oude Lansink, 1997).

1999). Micro-econometric simulation models provide detailed insight at the level of the farm (sometimes sector) and incorporate technological differences between farms (Oude Lansink and Peerlings, 1997; Vatn et al., 1997). However, they do not take into account the linkages with the rest of the economy. AGE models, on the other hand, focus on these linkages but are less detailed. Theoretically a link is possible, given that both types of model are based on micro-economic theory. However, when micro-econometric simulation models are to be incorporated in an AGE model, a number of requirements have to be met and problems to be solved. Some of the issues at stake are: (1) the aggregation level of both commodities and industries has to be equal in both approaches; (2) assumptions on factor demand (e.g., mobility of labour, capital and land) correspond; (3) increasing returns to scale technology in AGE models are difficult to deal with in order to find a unique equilibrium, which is less of a problem in micro-econometric models; (4) the estimated values of demand and supply should be consistent with the data given in the SAM and NAMEA.

Finally, it may be interesting in further research to consider regional differences in agriculture, using regional Social Accounting Matrices (SAMs). The appearance and functioning of rural areas is receiving increasing attention because of issues like rural employment and countryside maintenance (Strijker, 2000). Since agriculture contributes to rural activity and largely determines the appearance of the countryside, regional differentiation is appropriate. In addition, issues like wildlife conservation need further attention. However, regional SAMs should be in accordance with the national SAM while wildlife benefits are not represented in national accounts. Therefore, these topics also imply further needs for data development.

APPENDICES

Appendix I Model description

Demand and supply equations

Aggregate output is composed of a hypothetical aggregate energy input (AEN_b), a hypothetical aggregate materials input (AIN_b) and a hypothetical aggregate factor input (APR_b) according a CES production function with constant returns to scale (see glossary at the end of this appendix for overview of variables, coefficients and sets). Intermediate energy and material inputs ($IN_{b,g}$) are transformed into aggregate energy and aggregate materials input, respectively, according CES production functions with constant returns to scale. Labour ($PR_{b,1}$) and capital ($PR_{b,2}$) are transformed into the aggregate factor input, using a CES production function with constant returns to scale. Labour in the agricultural industries is composed of mobile (hired) labour and immobile (own) labour. Labour in the non-agricultural industries equals mobile labour, because it is assumed that there is no immobile labour. Cost minimisation yields CES demand functions for aggregate material, energy and factor inputs (I.1, I.2 and I.3 respectively), intermediate inputs (I.4 and I.5), factors (I.6), mobile labour (I.7 and I.9) and immobile labour (I.8):

$$AEN_b = f_{AEN_b}^{CES}(Y_b, WAEN_b, WAIN_b, WAPR_b) \quad \forall b \in B \quad (I.1)$$

$$AIN_b = f_{AIN_b}^{CES}(Y_b, WAEN_b, WAIN_b, WAPR_b) \quad \forall b \in B \quad (I.2)$$

$$APR_b = f_{APR_b}^{CES}(Y_b, WAEN_b, WAIN_b, WAPR_b) \quad \forall b \in B \quad (I.3)$$

$$IN_{b,g} = f_{IN_{b,g}}^{CES}(AEN_b, \boldsymbol{WIN_b}) \quad \forall b \in B, \forall g \in S_{en} \quad (I.4)$$

$$IN_{b,g} = f_{IN_{b,g}}^{CES}(AIN_b, \boldsymbol{WIN_b}) \quad \forall b \in B, \forall g \in S_{mat} \quad (I.5)$$

$$PR_{b,j} = f_{PR_{b,j}}^{CES}(APR_b, \boldsymbol{WPR_b}) \quad \forall b \in B, \forall j \in J \quad (I.6)$$

$$MPR_{b,1} = f_{MPR_{b,1}}^{CES}(PR_{b,1}, WMPR_{b,1}, WIPR_{b,1}) \quad \forall b \in S_{agr} \quad (I.7)$$

$$\overline{IPR_{b,1}} = f_{IPR_{b,1}}^{CES}(PR_{b,1}, WMPR_{b,1}, WIPR_{b,1}) \quad \forall b \in S_{agr} \quad (I.8)$$

$$MPR_{b,1} = PR_{b,1} \quad \forall b \notin S_{agr} \quad (I.9)$$

Supply of output g by industry b ($Y_{b,g}$) is proportional to the aggregate output (Y_b) by industry b (I.10). Aggregation of outputs over industries gives domestic production (DP_g) of commodity g (I.11):

$$Y_{b,g} = \delta_{b,g}^{Y}.Y_b \quad \sum_{g \in G} \delta_{b,g}^{Y} = 1 \quad \forall b \in B, \forall g \in G \quad (I.10)$$

$$DP_g = \sum_{b=1}^{B} Y_{b,g} \quad \forall g \in G \quad (I.11)$$

Domestic production (DP_g) and imports (IM_g) are aggregated into total supply of commodity g (SP_g) using a CES production function with constant returns to scale for commodities for which the Armington assumption is adopted. For these commodities, total supply is then divided into domestic use (DU_g) and exports (EX_g) using a CET product transformation function with constant returns to scale. Cost minimisation yields CES demand equations for domestic production (I.12) and imports (I.13) and revenue maximisation yields CET supply equations for domestic use (I.14) and exports (I.15):

$$DP_g = f_{DP_g}^{CES}(SP_g, WDP_g, WIM_g) \quad \forall g \in S_{arm} \quad (I.12)$$

$$IM_g = f_{IM_g}^{CES}(SP_g, WDP_g, WIM_g) \quad \forall g \in S_{arm} \quad (I.13)$$

$$DU_g = f_{DU_g}^{CET}(SP_g, WDU_g^{excl}, WEX_g) \quad \forall g \in S_{arm} \quad (I.14)$$

$$EX_g = f_{EX_g}^{CET}(SP_g, WDU_g^{excl}, WEX_g) \quad \forall g \in S_{arm} \quad (I.15)$$

Domestic production (DP_g) is equal to the sum of net trade ($TRAD_g$: exports minus imports) and domestic use (DU_g) for those commodities for which the homogeneity instead of the Armington assumption is adopted:

$$DP_g = TRAD_g + DU_g \qquad \forall g \in S_{hom} \qquad \text{(I.16)}$$

Total mobile labour (j=1) and total capital (j=2) available in the economy (TPR_j) are divided into supply of mobile labour ($MPR_{b,1}$) and capital ($PR_{b,2}$) by industry using CET product transformation functions with constant returns to scale. Revenue maximisation yields supply functions for mobile labour and capital (I.17 and I.18 respectively):

$$MPR_{b,1} = f^{CET}_{PR_{b,1}}(TPR_1, \boldsymbol{WMPR_1}) \qquad \forall b \in B \qquad \text{(I.17)}$$

$$PR_{b,2} = f^{CET}_{PR_{b,2}}(\overline{TPR_2}, \boldsymbol{WPR_2}) \qquad \forall b \in B \qquad \text{(I.18)}$$

Maximisation of the CES utility functions yields CES demand equations for the private household (I.19) and government (I.20):

$$X^{con}_g = f^{CES}_{con_g}(EXP^{con}, \boldsymbol{WDU^{con}}) \qquad \forall g \in S_{com} \qquad \text{(I.19)}$$

$$X^{gov}_g = f^{CES}_{gov_g}(EXP^{gov}, \boldsymbol{WDU}) \qquad \forall g \in S_{com} \qquad \text{(I.20)}$$

The demand for investment goods (X^{inv}_g) is given by:

$$X^{inv}_g = \delta^{inv}_g .INV \quad \sum_{g \in S_{com}} \delta^{inv}_g = 1 \qquad \forall g \in S_{com} \qquad \text{(I.21)}$$

Zero profit conditions

The value of disaggregated outputs equals the value of aggregate output and the value of aggregate inputs by industry:

$$\sum_{g \in G} WDP_g .Y_{b,g} = WY_b .Y_b \qquad \forall b \in B \qquad \text{(I.22)}$$

$$= WAEN_b .AEN_b + WAIN_b .AIN_b + WAPR_b .APR_b$$

The value of the aggregate energy and materials input equals the value of intermediate energy and materials inputs, respectively, by industry (I.23 and I.24). The value of the aggregate factor input equals the value of labour and capital by industry (I.25):

$$WAEN_b .AEN_b = \sum_{g \in S_{en}} WIN_{b,g} .IN_{b,g} \qquad \forall b \in B \qquad \text{(I.23)}$$

$$WAIN_b .AIN_b = \sum_{g \in S_{mat}} WIN_{b,g} .IN_{b,g} \qquad \forall b \in B \qquad \text{(I.24)}$$

$$WAPR^{excl}_b .APR_b = \sum_{j=1}^{2} WPR_{b,j} .PR_{b,j} \qquad \forall b \in B \qquad \text{(I.25)}$$

The value of total supply (SP_g) equals the value of domestic production and imports (I.26) and the value of domestic use and exports by commodity (I.27):

$$WSP_g .SP_g = WDP_g .DP_g + WIM_g .IM_g \qquad \forall g \in S_{arm} \qquad \text{(I.26)}$$

$$WSP_g.SP_g \quad = WDU_g^{excl}.DU_g + WEX_g.EX_g \qquad \forall g \in S_{arm} \qquad (I.27)$$

The value of the supply of mobile labour and capital equals the value of the total availability of labour and capital (I.28 and I.29 respectively). The value of mobile and immobile labour equals the value of total labour in the six agricultural industries (I.30). Moreover, in the non-agricultural industries the price of mobile labour equals the price of labour (I.31):

$$\sum_{b\in B} WMPR_{b,1}^{excl}.MPR_{b,1} = WTPR_1.TPR_1 \qquad (I.28)$$

$$\sum_{b\in B} WPR_{b,2}.PR_{b,2} = WTPR_2.\overline{TPR_2} \qquad (I.29)$$

$$WPR_{b,1}.PR_{b,1} = WIPR_{b,1}.\overline{IPR_{b,1}} + WMPR_{b,1}.MPR_{b,1} \qquad \forall b \in S_{agr} \qquad (I.30)$$

$$WMPR_{b,1} = WPR_{b,1} \qquad \forall b \notin S_{agr} \qquad (I.31)$$

The value of the demand for individual investment goods equals the expenditure on investment:

$$\sum_{g\in S_{com}} WDU_g.X_g^{inv} = WINV^{excl}.INV \qquad (I.32)$$

Margins
The total demand for wholesale margins, retail margins and export margins (*MAR*) is equal to supply:

$$MAR = \sum_{g\in S_{com}} (m_g^{dom}.WDU_g^{excl}.DU_g + m_g^{con}.WDU_g.X_g^{con}) + \sum_{g\in S_{arm}} m_g^{ex}.WEX_g.EX_g + \sum_{g\in S_{bom}} \mathrm{m}_g^{\mathrm{trad}}.WTRAD_g.TRAD_g \qquad (I.33)$$

$$DP_g = \frac{MAR}{WDP_g} \qquad \forall g \in S_{mar} \qquad (I.34)$$

Price equations
Indirect taxes and wholesale margins drive a wedge between the buyers' and sellers' price of domestic use (I.35). For industries the price of intermediate inputs equals the price of domestic use (I.36). Retail margins drive an additional wedge between the price of private household consumption and the price of domestic use (I.37):

$$WDU_g = (1 + t_g^{dom} + m_g^{dom}).WDU_g^{excl} \qquad \forall g \in S_{com} \qquad (I.35)$$

$$WIN_{b,g} = WDU_g \qquad \forall b \in B, \forall g \in S_{com} \qquad (I.36)$$

$$WDU_g^{con} = (1 + m_g^{con}).WDU_g \qquad \forall g \in S_{com} \qquad (I.37)$$

Taking into account export margins and taxes/subsidies, domestic import (WIM_g) and export prices (WEX_g) of commodities for which the Armington assumption is adopted are related to world market prices (respectively $WPIM_g$ and $WPEX_g$) according to:

$$\overline{WPIM_g}.ER = WIM_g \qquad \forall g \in S_{arm} \qquad (I.38)$$

$$\overline{WPEX_g}.ER = (1 + t_g^{ex} + m_g^{ex}).WEX_g \qquad \forall g \in S_{arm} \qquad (I.39)$$

Similarly, net trade prices ($WTRAD_g$) of commodities for which the Armington assumption is not adopted are related to world market prices ($WPTRAD_g$) according to:

$$\overline{WPTRAD_g}.ER \quad = (1+t_g^{trad}+m_g^{trad}).WTRAD_g \qquad \forall g \in S_{hom} \qquad (I.40)$$

Value added taxes are levied on total consumption (I.41). Investments are confronted with a value added tax and an investment tax. Moreover, the price of investments including taxes is equal to the price of private savings (I.42):

$$WCON \;=\; (1+t^{vatcon}).WCON^{excl} \qquad (I.41)$$

$$WSAV \;=\; WINV \;=\; (1+t^{vatinv}+t^{inv}).WINV^{excl} \qquad (I.42)$$

Indirect non-product related taxes and value added taxes[1] drive a wedge between the buyers' and sellers' price of the aggregate factor input (APR_b):

$$WAPR_b \;=\; (1+t_b^{apr}+t_b^{vatapr}).WAPR_b^{excl} \qquad \forall b \in B \qquad (I.43)$$

Employers in each industry pay labour taxes on mobile labour (I.44). Suppliers of labour (employees) and capital pay labour taxes (I.45) and capital taxes (I.46), respectively. These taxes are all modelled as ad valorem taxes:

$$WMPR_{b,1} \;=\; WMPR_{b,1}^{excl}.(1+t_b^{labsec}) \qquad \forall b \in B \qquad (I.44)$$

$$WTPR_1 \;=\; WTPR_1^{excl}.(1+t^{labtot}) \qquad (I.45)$$

$$WTPR_2 \;=\; WTPR_2^{excl}.(1+t^{captot}) \qquad (I.46)$$

The price of leisure is equal to the price of labour, corrected for income taxes:

$$WLEIS \;=\; WTPR_1^{excl}.(1-t^{inc}) \qquad (I.47)$$

Equilibrium conditions

Total domestic use equals intermediate, private household, government and investment demand:

$$DU_g \;=\; \sum_{b \in B} IN_{b,g} + X_g^{con} + X_g^{gov} + X_g^{inv} \qquad \forall g \in S_{com} \qquad (I.48)$$

Income formation and distribution

Labour income (I^{lab}), gross capital income (I^{gcap}), net capital income (I^{ncap}) and capital depreciation (DEP) are given by:

$$I^{lab} \;=\; WTPR_1^{excl}.TPR_1 + \sum_{b \in S_{agr}} WIPR_{b,1}.\overline{IPR_{b,1}} + \overline{TR^{lab}}.ER \qquad (I.49)$$

$$I^{gcap} \;=\; WTPR_2.TPR_2 \qquad (I.50)$$

$$I^{ncap} \;=\; I^{gcap}.(1-r^{dep}) \qquad (I.51)$$

[1] Value added tax (VAT) is normally imposed (and modelled accordingly) on final use (consumption and investments). For a few services producing industries, however, sales are exempted from VAT. Hence, in those industries VAT paid on intermediate inputs cannot be deducted from received VAT. Since the division of VAT over intermediate inputs is not known, they are modelled as taxes on factor input (value added).

$$DEP = I^{gcap}.r^{dep} \tag{I.52}$$

Private household income (I^{con}) is given by net capital income (I^{ncap}), labour income (I^{lab}) and domestic income transfers (I^{trans}) corrected for income taxes, expenditure on leisure and the balance of exogenous income transfers with the rest of the world:

$$I^{con} = (I^{ncap} + I^{lab} + I^{trans}).(1 - t^{inc}) + WLEIS.LEIS + \overline{TR^{con}}.ER \tag{I.53}$$

The welfare of the representative private household is determined by future consumption (savings), leisure and current consumption according a nested CES utility function. In the first stage of the multi-stage budgeting a choice is made between future consumption (*SAV*) and current consumption (*CUR*: a composite of leisure and aggregate consumption). In the second stage, the current budget is divided into leisure (*LEIS*) and aggregate consumption (*CON*). Total imperfectly mobile labour supply (TPR_1) hence results from the difference between the time endowment (*TLAB*) and leisure (*LEIS*). The following equations hold:

$$SAV = f_{SAV}^{CES}(I^{con}, WSAV, WCUR) \tag{I.54}$$

$$CUR = f_{CUR}^{CES}(I^{con}, WSAV, WCUR) \tag{I.55}$$

$$LEIS = f_{LEIS}^{CES}(EXP^{cur}, WLEIS, WCON) \tag{I.56}$$

$$CON = f_{CON}^{CES}(EXP^{cur}, WLEIS, WCON) \tag{I.57}$$

$$TPR_1 = \overline{TLAB} - LEIS \tag{I.58}$$

Tax revenues (*TX*) are given by:

$$\begin{aligned} TX = {} & \sum_{g \in S_{com}} t_g^{dom}.WDU_g^{excl}.DU_g + \\ & \sum_{g \in S_{arm}} t_g^{ex}.WEX_g.EX_g + \sum_{g \in S_{hom}} t_g^{trad}.WTRAD_g.TRAD_g + \\ & \sum_{b \in B} \left((t_b^{apr} + t_b^{vatapr}).WAPR_b^{excl}.APR_b + t_b^{labsec}.WMPR_{b,1}^{excl}.MPR_{b,1} \right) + \\ & t^{labtot}.WTPR_1^{excl}.TPR_1 + t^{captot}.WTPR_2^{excl}.TPR_2 + \\ & t^{vatcon}.WCON^{excl}.CON + \\ & (t^{vatinv} + t^{inv}).WINV^{excl}.INV + (I^{ncap} + I^{lab} + I^{trans}).t^{inc} \end{aligned} \tag{I.59}$$

The government deficit (*DEF*) is assumed to be a fixed part of tax revenues:

$$DEF = r^{def}.TX \tag{I.60}$$

The government budget (I^{gov}) is determined by tax revenues (*TX*) and government deficit (*DEF*) corrected for the balance of income transfers with the rest of the world (TR^{gov}):

$$I^{gov} = TX + DEF + \overline{TR^{gov}}.ER \tag{I.61}$$

The government budget is used for domestic income transfers (I^{trans}) and public expenditures (EXP^{gov}):

$$EXP^{gov} = I^{gov}.r^{gov}_{exp}$$
$$r^{gov}_{exp} + r^{gov}_{trans} = 1 \qquad (I.62)$$
$$I^{trans} = I^{gov}.r^{gov}_{trans}$$

Total value of investments is determined by private savings and capital depreciation corrected for the government deficit and the balance of trade:

$$WINV.INV = WSAV.SAV + DEP - DEF - \overline{BBAR}.ER \qquad (I.63)$$

Trade balance
The trade balance ($BBAR$) is assumed to be fixed:

$$\overline{BBAR} = -\sum_{g \in S_{arm}} \overline{WPIM_g}.IM_g + \sum_{g \in S_{arm}} \overline{WPEX_g}.EX_g + \sum_{g \in S_{hom}} \overline{\mathrm{WPTRAD}_g}.TRAD_g - \overline{TR^{lab}} - \overline{TR^{con}} - \overline{TR^{gov}} \qquad (I.64)$$

Price numéraire
The price numéraire ($PNUM$) is given by:

$$\overline{PNUM} = \frac{\sum_{b \in B} \overline{Y_b^{old}}.WY_b}{\sum_{b \in B} \overline{Y_b^{old}}.\overline{WY_b^{old}}} = 1 \qquad (I.65)$$

Environment
Emissions (EM_m), are linked to intermediate inputs, aggregate output, consumer goods and aggregate consumption (I.66).

$$EM_m = \sum_{b=1}^{B} \sum_{g \in S_{com}} \xi^{IN}_{m,g,b}.IN_{g,b} + \sum_{b=1}^{B} \xi^{Y}_{m,b}.Y_b + \sum_{g \in S_{com}} \xi^{X^{con}}_{m,g}.X^{con}_g + \xi^{CON}_m.CON \qquad \forall m \in M \qquad (I.66)$$

Welfare change
Welfare change measured by the equivalent variation is equal to the difference in expenditures on a household consumption bundle between utility levels in two equilibria (e.g. before and after a policy change), using the prices of the initial equilibrium. The equivalent variation for the private household can be calculated at all (sub)utility levels of the multi-stage budgeting: the equivalent variation at sub-utility level aggregate consumption ($EQVAR_{CON}$, I.67); the equivalent variation at sub-utility level current consumption ($EQVAR_{CUR}$, I.68); and the equivalent variation at total utility level of the private household ($EQVAR^{con}$, I.69). Similarly, the welfare change from public consumption ($EQVAR^{gov}$) can be derived (I.70).

$$EQVAR_{CON} = e(CON, \overline{\mathbf{WDU}_g^{con,old}}) - e(\overline{CON^{old}}, \overline{\mathbf{WDU}_g^{con,old}}) \qquad (I.67)$$

$$EQVAR_{CUR} = e(CUR, \overline{WLEIS^{old}}, \overline{WCON^{old}}) - e(\overline{CUR^{old}}, \overline{WLEIS^{old}}, \overline{WCON^{old}}) \qquad (I.68)$$

$$EQVAR^{con} = e(\overline{U^{con}}, \overline{WSAV^{old}}, \overline{WCUR^{old}}) - e(\overline{U^{con,old}}, \overline{WSAV^{old}}, \overline{WCUR^{old}}) \quad (I.69)$$

$$EQVAR^{gov} = e(U^{gov}, \overline{\mathbf{WDU}_g^{old}}) - e(\overline{U^{gov,old}}, \overline{\mathbf{WDU}_g^{old}}) \quad (I.70)$$

where $e(U,w)$ are expenditure functions, measuring expenditures at (sub)utility level U, given prices w.[2]

An alternative welfare measure is the Laspeyres measure of real income change, which compares commodity bundles between two equilibria (e.g. before and after a policy change), using the prices of the initial equilibrium (I.71). This welfare measure allows for the calculation of the welfare effects of savings other than the private savings of which the underlying optimising behaviour is not modelled explicitly (i.e. capital depreciation, government deficit and the balance of trade).[3] Since savings are equal to investments, the bundle of investment commodities represent welfare derived from saving.

$$\begin{aligned} WELF = & \sum_{g \in S_{com}} \overline{WDU_g^{con,old}}.X_g^{con} - \sum_{g \in S_{com}} \overline{WDU_g^{con,old}}.\overline{X_g^{con,old}} + \\ & \overline{WLEIS^{old}}.LEIS - \overline{WLEIS^{old}}.\overline{LEIS^{old}} + \\ & \sum_{g \in S_{com}} \overline{WDU_g^{old}}.X_g^{inv} - \sum_{g \in S_{com}} \overline{WDU_g^{old}}.\overline{X_g^{inv,old}} + \\ & \sum_{g \in S_{com}} \overline{WDU_g^{old}}.X_g^{gov} - \sum_{g \in S_{com}} \overline{WDU_g^{old}}.\overline{X_g^{gov,old}} \end{aligned} \quad (I.71)$$

Glossary

Variables:

AEN: aggregate energy inputs
AIN: aggregate materials inputs
APR: aggregate factor inputs
BBAR: balance of trade (in dollar)
CON: private current consumption
CUR: private current expenditures
DEF: government deficit
DEP: capital depreciation
DP: domestic production
DU: domestic use
EN: environmental themes
EQVAR: equivalent variation
ER: exchange rate (in guilder per dollar)
EX: exports

[2] *CON* and *CUR* are sub-utility levels in the multi-stage budgeting and therefore take the form of both utility and quantity. Hence *CON* and *CUR* occur in the expenditure functions to define equivalent variation at sub-utility levels (Shoven and Whalley, 1992, p.192).

[3] For sub-utility levels the Laspeyres measure of real income change and the equivalent variation are identical (Shoven and Whalley, 1992, p.192):

$$EQVAR_{CON} = e(CON, \overline{WDU_g^{con,old}}) - e(\overline{CON^{old}}, \overline{WDU_g^{con,old}}) = \overline{WCON^{old}}.CON - \overline{WCON^{old}}.\overline{CON^{old}}$$

$$EQVAR_{CUR} = e(CUR, \overline{WLEIS^{old}}, \overline{WCON^{old}}) - e(\overline{CUR^{old}}, \overline{WLEIS^{old}}, \overline{WCON^{old}}) = \overline{WCUR^{old}}.CUR - \overline{WCUR^{old}}.\overline{CUR^{old}}$$

EXP: expenditure
I: income
IM: imports
IN: intermediate inputs
INV: investments
IPR: immobile factor inputs
LEIS: leisure
MAR: market margins
MPR: mobile factor inputs
PNUM: price numéraire
PR: factor inputs
SAV: private savings
SP: total supply
TPR: total factor inputs
TR: net transfers from the rest of the world (in dollar)
TRAD: net export of homogeneous commodities
TX: tax revenues
W: domestic prices
WELF: welfare change
WP: world market prices
X: consumer, government and investment demand
Y: outputs

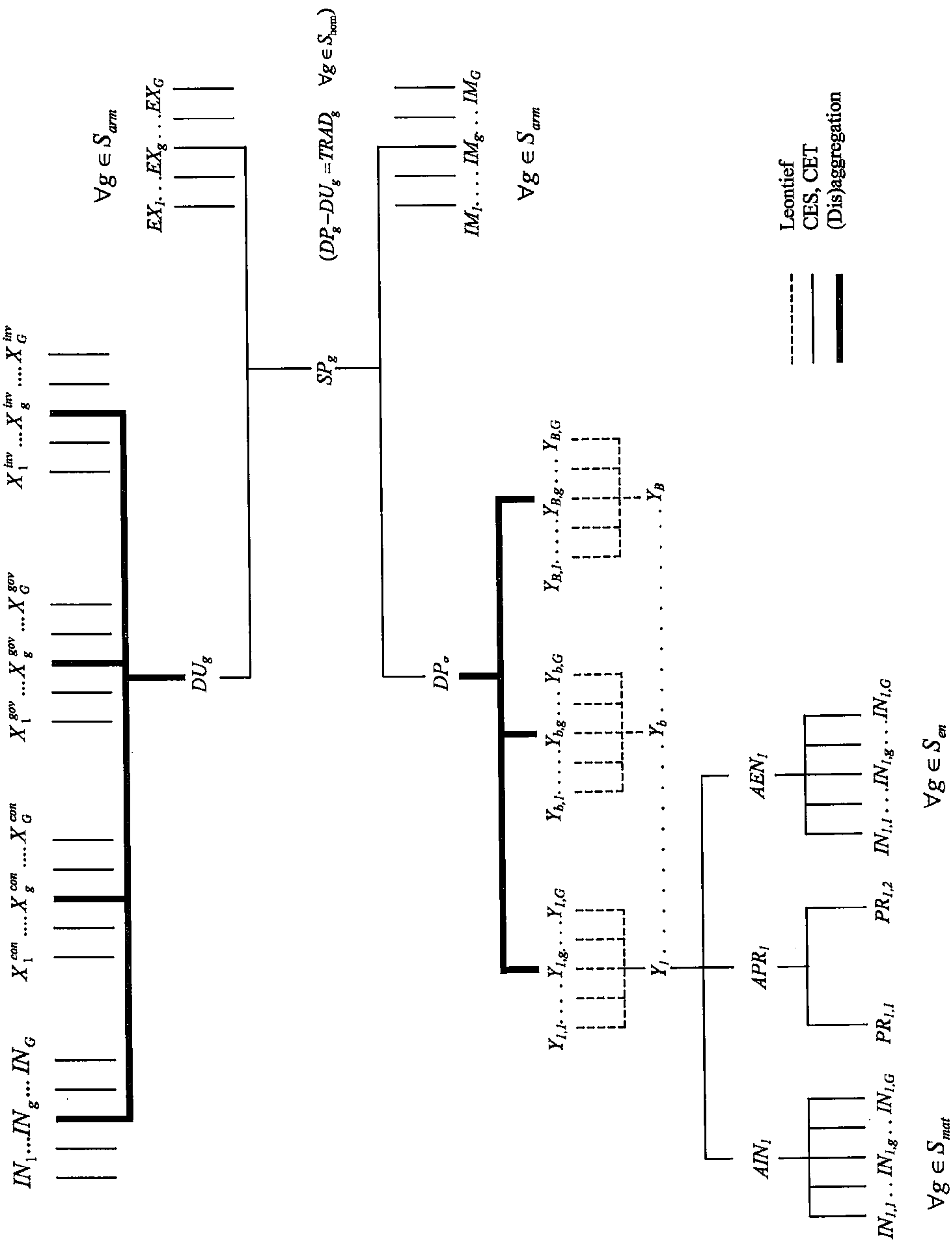
Coefficients:
m: market margin rates
r: rate (government deficit, expenditure, income transfers, capital depreciation)
t: tax rates
δ: input-output coefficient
ξ: emission coefficient

Sets and subsets:
B: industries, b = 1 to 37 (see appendix IV)
G: goods, g = 1 to 45 (see appendix IV)
J: factors, j = 1 (labour) j = 2 (capital)
M: emissions, m = 1 to 9 (see appendix IV)
$S_{agr} \subset B$: subset agricultural industries: b = 1,…,6
$S_{arm} \subset G$: subset Armington commodities: g = 1,3,…,12,14,…,44
$S_{com} \subset G$: subset commodities: g = 1,…,44
$S_{en} \subset G$: subset energy commodities: g = 24,27,…,30
$S_{hom} \subset G$: subset homogeneous commodities: g = 2,13
$S_{mar} \subset G$: subset trade and transport margins: g = 45
$S_{mat} \subset G$: subset materials: g = 1,…,23,25,26,31,…,44

Miscellaneous
captot = total capital; CES = Constant Elasticity Substitution; CET = Constant Elasticity of Transformation; con = private household; dom = domestic; en = energy; excl = excluding taxes and margins; gov = government; inc = income; inv = investment; lab = labour; labsec = mobile labour by industry; labtot = total labour; ncap = net capital; old = base year value; trans = domestic transfer; vatapr = VAT aggregate factor input; vatcon = VAT consumption; vatinv = VAT investments.

Bold printed variables represent a vector; variables with a bar represent exogenous variables.

Figure I.1 Production structure of the AGE model



Appendix II Social Accounting Matrices

Table II.1 *Social Accounting Matrix 1990 for the Netherlands*[a]

Account	Commodities	Production	Income formation				Income distribution		Institutions						
	1. Commodities	2. Industries	3a. Labour income	3b. Labour tax employer	4. Capital income	5. Taxes	6. House-holds	7. Govern-ment	8. House-holds	9. Govern-ment	10. Capital	11. Invest-ment	12. R.o.w. current	13. R.o.w. capital	14. Total
Commodities															
1. Commodities		471829							280134	74795		105640	279746		1212144
Production															
2. Industries	948964														948964
Income formation															
3a. Labour income		239939													239939
3b. Labour tax employer		27803													27803
4. Capital income		198924				1614									200538
5a. Non-prod. related taxes		3269													3269
5b. VAT		7200							22962			8426			38588
5c. Net tax on investment												392			392
Income distribution															
6. Households			190609		122638			149913							463160
7. Government.	7352		49050	27803	19670	40635	74610								219120
Institutions															
8. Households							391320								391320
9. Government								62557							62557
10. Capital					58230				88224	-12238					134216
11. Investment											114458				114458
12. R.o.w. current	255828		280				-2770	6650						19758	279746
13. R.o.w. capital											19758				19758
14. **Total**	1212144	948964	239939	27803	200538	42249	463160	219120	391320	62557	134216	114458	279746	19758	

[a] Million 1990 guilders
Source: CBS-1 (1993)

ɔle II.2 *Social Accounting Matrix 1993 for the Netherlands*[a]

ccount	**Commodities** 1. Commodities	**Production** 2. Industries	**Income formation** 3a. Labour income	3b. Labour tax employer	4. Capital income	5. Taxes	**Income distribution** 6. House-holds	7. Govern-ment	**Institutions** 8. House-holds	9. Govern-ment	10. Capital	11. Invest-ment	12. R.o.w. current	13. R.o.w. capital	14. Total
ommodities															
Commodities	0	501332							326604	86215		98773	293180		1306104
roduction															
Industries	1037273														1037273
ıcome formation															
ι. Labour income		277260													277260
). Labour tax employer		31509													31509
Capital income		213167				1955									215122
ι. Non-prod. related taxes		5785													5785
). VAT		8220							25117			8558			41895
:. Net tax on investment												516			516
come distribution															
Households			217290		125502			173119							515911
Government.	11329		59760	31509	21010	46241	94740								264589
stitutions															
Households							426141								426141
Government								79330							79330
). Capital					68610				74420	-6885					136145
l. Investment											107847				107847
?. R.o.w. current	257502		210				-4970	12140						28298	293180
}. R.o.w. capital											28298				28298
ŀ. Total	1306104	1037273	277260	31509	215122	48196	515911	264589	426141	79330	136145	107847	293180	28298	

Million 1993 guilders
rce: CBS-1 (1996)

Appendix III Eliminating hidden data

Consider a matrix A, representing the make table of the Dutch economy.

$$A^{old} = \begin{bmatrix} M^1_{i,j} & S^1_{i,j+1} \\ S^2_{i+1,j} & s_{i+1,j+1} \end{bmatrix} \tag{III.1}$$

In this matrix, $M^1_{i,j}$ is a matrix for all the known commodities and industries where each entry m^1_{ij} is the value of commodity i produced by industry j. $S^1_{i,j+1}$ is a column vector of i commodities produced by an unknown (hidden) industry $j+1$. $S^2_{i+1,j}$ is a row vector of j industries producing an unknown (hidden) commodity $i+1$. $s_{i+1,j+1}$ is a balancing scalar for which the following conditions hold:

$$s_{i+1,j+1} = -\sum_i S^1_{i,j+1} = -\sum_j S^2_{i+1,j} \tag{III.2}$$

Sometimes a clear relationship is observed between commodities of column vector S^1 and industries of row vector S^2 (e.g. fertiliser is clearly produced by the fertiliser industry). Hence, a matrix $M^2_{i,j}$ can be identified where each entry m^2_{ij} is the value of commodity i produced by industry j which was unknown in matrix A^{old}. Now define the following matrix:

$$B = \begin{bmatrix} M^2_{i,j} & E^1_{i,j+1} \\ E^2_{i+1,j} & e_{i+1,j+1} \end{bmatrix} \tag{III.3}$$

for which the following conditions hold:

$$E^1_{i,j+1} = -\sum_j M^2_{i,j} \tag{III.4}$$

$$E^2_{i+1,j} = -\sum_i M^2_{i,j} \tag{III.5}$$

$$e_{i+1,j+1} = \sum_i \sum_j M^2_{i,j} \tag{III.6}$$

To eliminate (part of) the hidden industries and commodities a new make table A^{new} of the Dutch economy can be derived:

$$A^{new} = A^{old} + B \tag{III.7}$$

The same procedure can be applied for the use tables.

Appendix IV

Classification of industries, commodities, emissions and environmental indicators

Industries

B1	Dairy farming and other animal production
B2	Pig farming
B3	Poultry farming
B4	Arable farming
B5	Horticulture under glass
B6	Other horticulture
B7	Forestry and agricultural services
B8	Fishery
B9	Beef and other meat industry
B10	Pig meat industry
B11	Poultry meat industry
B12	Dairy products manufacturing
B13	Compound feed industry
B14	Sugar industry
B15	Margarine industry
B16	Starch industry
B17	Other food products manufacturing
B18	Oil and gas extraction
B19	Other mining industries
B20	Clothing/wood/paper industry
B21	Petroleum industry
B22	Fertiliser industry
B23	Chemical pesticides manufacturing
B24	Other chemical industries
B25	Synthetics and building materials industry
B26	Basic metal industry
B27	Machinery and metal products manufacturing
B28	Transport equipment industry
B29	Electrical products and other industries
B30	Electricity supply
B31	Gas distribution
B32	Water supply
B33	Construction
B34	Wholesale and retail trade
B35	Transport and storage industry
B36	Cleaning services industry
B37	Other services

Emissions

M1	CO_2
M2	NO_x
M3	SO_2
M4	N_2O
M5	CH_4
M6	NH_3
M7	P
M8	N
M9	Waste

Environmental indicators

GHG	Greenhouse gases
ACID	Acidification
EUT	Eutrophication
WST	Waste accumulation

Commodities

G1	Cattle and other animals
G2	Pigs
G3	Poultry
G4	Flowers and plants
G5	Grain
G6	Other arable farming products
G7	Milk
G8	Vegetables and fruits
G9	Oils and fat
G10	Starch
G11	Compound feed
G12	Dairy products
G13	Eggs
G14	Fish and fish products
G15	Beef and other meat
G16	Pig meat
G17	Poultry meat
G18	Sugar
G19	Other agricultural/food products
G20	Beverages and tobacco
G21	Raw materials leather/textiles/paper
G22	Other minerals
G23	Building materials
G24	Coal
G25	Other raw materials energy
G26	Fuels for vehicles
G27	Other fuels for heating
G28	Natural gas[a]
G29	Distributed gas[a]
G30	Electricity
G31	Water
G32	Fertiliser
G33	Other chemical products
G34	Pesticides
G35	Rubber and synthetics
G36	Semi-manufactured metal products
G37	Metal products and machinery
G38	Transport equipment and parts
G39	Furniture, electronics, packing etc.
G40	Garden and agricultural services
G41	Construction and ground work
G42	Transport services
G43	Cleaning services
G44	Other services
G45	Trade and transport margins

Groups of industries

Agriculture:	B1-B6
Agribusiness:	B7, B9-B17
Other industries:	B8, B18-B29, B33
Public utilities:	B30-B32
Services:	B34-B37

[a] Natural gas and distributed gas are different commodities. Natural gas is provided directly to large users and gas distribution companies. Distributed gas is provided to small users, using the gas distribution network.

Appendix V Make and use tables

Table V.1 *Summarised make table 1990*[a]

		B1 Dairy farming	B2 Pig farming	B3 Poultry farming	B4 Arable farming	B5 Horticult. under glass	B6 Other horticult.	B9 Beef industry	B10 Pig meat industry	B11 Poultry meat industry	Total domestic production	Imports	Total
G1	Cattle	4516									4516	642	5158
G2	Pigs		7649								7651	24	7675
G3	Poultry			1422							1424	82	1506
G4	Flowers and plants					4901	1899				7057	834	7891
G5	Grain				460						460	1943	2403
G6	Arable products n.e.c.				3087						3096	4823	7919
G7	Milk	7959									7959		7959
G8	Vegetables/fruits					2458	2723				5206	2826	8032
G9	Oils and fat							110	114	1	2780	1072	3852
G10	Starch										1380	386	1766
G11	Compound feed									9	8520	383	8903
G12	Dairy products	72									12324	3416	15740
G13	Eggs			1129							1129	48	1177
G14	Fish and fish products										2154	1335	3489
G15	Beef and other meat							4908	485	56	5464	952	6416
G16	Pig meat								7838		7842	223	8065
G17	Poultry meat									2083	2083	298	2381
G18	Sugar										1707	125	1832
G19	Food products n.e.c.	6						150	253	65	21917	7814	29731
G20	Beverages and tobacco										8541	3011	11552
G21	Raw mat.leather/textiles/paper	149						267			31227	21404	52631
G22	Other minerals										838	2184	3022
G23	Building materials										12609	8301	20910
G24	Coal											1755	1755
G25	Other raw materials energy										9256	18390	27646
G26	Fuels for vehicles										11609	2056	13665
G27	Other fuels for heating										2996	947	3943
G28	Natural gas										15412	418	15830
G29	Distributed gas										7905		7905
G30	Electricity										9620	415	10035

Table V.1 continued

		B1 Dairy farming	B2 Pig farming	B3 Poultry farming	B4 Arable farming	B5 Horticult. under glass	B6 Other horticult.	B9 Beef industry	B10 Pig meat industry	B11 Poultry meat industry	Total domestic production	Imports	Total
G31	Water										1953		1953
G32	Fertiliser										1934	436	2370
G33	Other chemical products										42246	24722	66968
G34	Pesticides										553	467	1020
G35	Rubber and synthetics										1016	670	1686
G36	Semi-manufact. metal products										15737	14003	29740
G37	Metal products and machinery										34093	41964	76057
G38	Transport equipment and parts										16030	21366	37396
G39	Furniture, electr., packing etc.							1	1		37693	30938	68631
G40	Garden and agricultural services										2944		2944
G41	Construction and ground work										77850	58	77908
G42	Transport services										33109		33109
G43	Cleaning services										2536		2536
G44	Other services							59	99	26	369663	35097	404760
G45	Trade and transport margins	32	20	6	9	19	12	13	22	6	96925		96925
TOTAL MAKE		12734	7669	2557	3556	7378	4634	5508	8812	2246	**948964**	**255828**	**1204792**

[a] Million 1990 guilders in sellers' prices

Sources: CBS-2 (1993), CBS-3 (1993) and own calculations

Table V.2 *Summarised use table 1990*[a]

		B1 Dairy farming	B2 Pig farming	B3 Poultry farming	B4 Arable farming	B5 Hort. glass	B6 Hort. other.	B9 Beef industry	B10 Pig meat industry	B11 Poultry meat industry	Total inter-mediate use	Cons.+ Invest.	Exports	Margins	Taxes/ Subsidies	Total
G1	Cattle	1025						4346			5371	150	389	-769	17	5158
G2	Pigs		1375						5613		6988	31	1040	-384		7675
G3	Poultry			17						1402	1419	14	250	-180	3	1506
G4	Flowers and plants					246	188		1		981	2036	7057	-2110	-73	7891
G5	Grain	38	24								2470	-1	197	-228	-35	2403
G6	Arable products n.e.c.	375	6		324		44				7319	448	1928	-1724	-52	7919
G7	Milk										7904	55				7959
G8	Vegetables/fruits					128	141				1331	4325	5523	-3045	-102	8032
G9	Oils and fat							50	65	16	2287	549	1425	-372	-37	3852
G10	Starch							4	4	1	627	-15	1306	-264	112	1766
G11	Compound feed	2750	3600	1517							8345	-1	963	-449	45	8903
G12	Dairy products	3						3	4	1	3758	5540	6931	-2034	1545	15740
G13	Eggs			18							218	362	934	-372	35	1177
G14	Fish and fish products										1094	935	2443	-945	-38	3489
G15	Beef and other meat							247			831	4067	3203	-1797	112	6416
G16	Pig meat								1268		1811	3228	4737	-1747	36	8065
G17	Poultry meat									286	414	912	1383	-325	-3	2381
G18	Sugar										1276	257	437	-254	116	1832
G19	Food products n.e.c.	81						42	55	14	10309	13806	11149	-5579	46	29731
G20	Beverages and tobacco										3390	9281	5890	-2788	-4221	11552
G21	Raw mat.leather/textiles/paper	23	4	1	7	4	5	28	36	9	25687	25893	14206	-13002	-153	52631
G22	Other minerals					37	14				3203	111	691	-983		3022
G23	Building materials	34	6	1	9	33	7				18546	3093	4174	-4878	-25	20910
G24	Coal										1657	165	244	-171	-140	1755
G25	Other raw materials energy	21	1		13	24	4		1		22721	1293	4288	-651	-5	27646
G26	Fuels for vehicles	156	12	4	85	17	33	6	8	2	5311	6207	10206	-2150	-5909	13665
G27	Other fuels for heating	2	2	1		35	2	1	1		1062	8	3112	-197	-42	3943
G28	Natural gas							1	2	1	10215		5799		-184	15830
G29	Distributed gas	45	52	15	7	766	50	10	13	3	3328	4577				7905
G30	Electricity	132	42	14	22	101	36	22	28	7	7257	2747	31			10035

Table V.2 continued

		B1 Dairy farming	B2 Pig farming	B3 Poultry farming	B4 Arable farming	B5 Hort. glass	B6 Hort. Other.	B9 Beef industry	B10 Pig meat industry	B11 Poultry meat industry	Total inter-mediate use	Cons.+ Invest.	Exports	Margins	Taxes/ Subsidies	Total
G31	Water	71	22	8	7	22	8	1	1	1	607	1346				1953
G32	Fertiliser	424	8		236	23	14				937	43	1794	-403	-1	2370
G33	Other chemical products	41	7	2	12	8	9	14	19	5	28935	9388	38786	-9853	-288	66968
G34	Pesticides	31	3	1	165	50	62				506	84	600	-168	-2	1020
G35	Rubber and synthetics										801	31	978	-123	-1	1686
G36	Semi-manufact. metal products	9						1	1	1	19807	1151	12867	-4041	-44	29740
G37	Metal products and machinery	18	3	1	5	4	4	7	9	2	26487	26896	36035	-12742	-619	76057
G38	Transport equipment and parts										8443	23214	13635	-4961	-2935	37396
G39	Furniture, electr., packing etc.				8	139	88	127	164	41	23926	37085	25225	-17236	-369	68631
G40	Garden and agricultural services	547	60	14	777	204	125		1		2747	197				2944
G41	Construction and ground work	121	48	11	59	61	69	10	12	3	30338	46012	1558			77908
G42	Transport services	1						3	4	1	4579	5360	19566		3604	33109
G43	Cleaning services	13	2	1	4	2	3	6	8	2	1288	1248				2536
G44	Other services	943	190	43	231	680	640	254	327	81	155298	218441	28766		2255	404760
G45	Trade and transport margins													96925		96925
Total intermediate use		6904	5467	1669	1971	2584	1546	5183	7645	1879	**471829**	**460569**	**279746**	**0**	**-7352**	**1204792**
Non product related taxes/subsidies		276	47	10	63	109	123	51	81	21	**10469**					
Wages/social premiums hired labour		120	54	27	185	1168	520	158	635	279	**260172**					
Self employed labour income		3133	945	228	903	1233	1128				**7570**					
Capital income		2301	1156	623	434	2284	1317	116	451	67	**198924**					
TOTAL USE		12734	7669	2557	3556	7378	4634	5508	8812	2246	**948964**					

[a] Million 1990 guilders in buyers' prices

Sources: CBS-2 (1993), CBS-3 (1993) and own calculations

Table V.3 *Summarised make table 1993*[a]

		B1 Dairy farming	B2 Pig farming	B3 Poultry farming	B4 Arable farming	B5 Horticult. under glass	B6 Other horticult.	B9 Beef industry	B10 Pig meat industry	B11 Poultry meat industry	Total domestic production	Imports	Total
G1	Cattle	4469									4469	865	5334
G2	Pigs		5630								5635	91	5726
G3	Poultry			1390							1392	155	1547
G4	Flowers and plants					5415	2223				7893	1064	8957
G5	Grain				410						410	2219	2629
G6	Arable products n.e.c.				2523						2532	4308	6840
G7	Milk	7941									7941		7941
G8	Vegetables/fruits					2274	2323				4602	3468	8070
G9	Oils and fat							149	41	3	3249	1361	4610
G10	Starch										1420	442	1862
G11	Compound feed									35	8642	305	8947
G12	Dairy products	72									12773	4292	17065
G13	Eggs			1018							1018	114	1132
G14	Fish and fish products										2120	1443	3563
G15	Beef and other meat							5939	509	60	6535	1248	7783
G16	Pig meat								6400		6406	291	6697
G17	Poultry meat									2468	2468	512	2980
G18	Sugar										1558	151	1709
G19	Food products n.e.c.	6						177	206	75	24006	8415	32421
G20	Beverages and tobacco										9873	3367	13240
G21	Raw mat.leather/textiles/paper	144						228			30804	20924	51728
G22	Other minerals										734	1713	2447
G23	Building materials										12981	8025	21006
G24	Coal											1289	1289
G25	Other raw materials energy										6899	14829	21728
G26	Fuels for vehicles										10985	1080	12065
G27	Other fuels for heating										2593	558	3151
G28	Natural gas										16450	461	16911
G29	Distributed gas										9248		9248
G30	Electricity										10460	389	10849

Table V.3 continued

		B1 Dairy farming	B2 Pig farming	B3 Poultry farming	B4 Arable farming	B5 Horticult. under glass	B6 Other horticult.	B9 Beef industry	B10 Pig meat industry	B11 Poultry meat industry	Total domestic production	Imports	Total
G31	Water										2316		2316
G32	Fertiliser										1470	383	1853
G33	Other chemical products										38222	25001	63223
G34	Pesticides										585	481	1066
G35	Rubber and synthetics										707	672	1379
G36	Semi-manufact. metal products										14209	11104	25313
G37	Metal products and machinery										35537	41806	77343
G38	Transport equipment and parts										14459	20368	34827
G39	Furniture, electr., packing etc.							1	1		35837	32309	68146
G40	Garden and agricultural services										3264		3264
G41	Construction and ground work										83655	35	83690
G42	Transport services										38885		38885
G43	Cleaning services										3578		3578
G44	Other services							62	71	25	440224	41964	482188
G45	Trade and transport margins	35	16	7	8	21	13	22	25	9	108229		108229
TOTAL MAKE		12667	5646	2415	2941	7710	4559	6578	7253	2675	**1037273**	**257502**	**1294775**

[a] Million 1993 guilders in sellers' prices

Sources: CBS-2 (1996), CBS-3 (1996) and own calculations

Table V.4 *Summarised use table 1993*[a]

		B1 Dairy farming	B2 Pig farming	B3 Poultry farming	B4 Arable farming	B5 Hort. glass	B6 Hort. Other.	B9 Beef industry	B10 Pig meat industry	B11 Poultry meat industry	Total inter-mediate use	Cons.+ Invest.	Exports	Margins	Taxes/ Subsidies	Total
G1	Cattle	1192						4819			6011	-274	459	-884	22	5334
G2	Pigs		813						4475		5288	38	912	-512		5726
G3	Poultry			43						1451	1494	43	232	-226	4	1547
G4	Flowers and plants					359	147	1			1257	2163	8096	-2467	-92	8957
G5	Grain	69	17								2453	-52	365	-236	99	2629
G6	Arable products n.e.c.	323	5		200		36				6086	595	1874	-1718	3	6840
G7	Milk										7893	48				7941
G8	Vegetables/fruits					119	121				1327	4333	6162	-3654	-98	8070
G9	Oils and fat							68	63	20	2582	663	1882	-487	-30	4610
G10	Starch							5	5	1	656	16	1326	-304	168	1862
G11	Compound feed	2432	3417	1791							8131		1324	-527	19	8947
G12	Dairy products	4						3	2	1	4258	5522	7604	-2358	2039	17065
G13	Eggs			42							268	390	829	-399	44	1132
G14	Fish and fish products										1138	1061	2461	-1055	-42	3563
G15	Beef and other meat							316			1020	4385	4020	-2080	438	7783
G16	Pig meat								1310		1879	3420	3622	-2270	46	6697
G17	Poultry meat									545	703	919	1806	-476	28	2980
G18	Sugar										1287	245	290	-269	156	1709
G19	Food products n.e.c.	85						34	31	10	11205	14970	12597	-6554	203	32421
G20	Beverages and tobacco										3973	10793	7047	-3448	-5125	13240
G21	Raw mat. leather/textiles/paper	36	5	1	9	6	8	31	29	9	24861	27850	14387	-15160	-210	51728
G22	Other minerals					30	13				2747	104	617	-1021		2447
G23	Building materials	43	6	2	10	21	9				19004	2944	4465	-5384	-23	21006
G24	Coal										1512	7	241	-169	-302	1289
G25	Other raw materials energy	18	1		10	23	4	1			18617	171	3699	-752	-7	21728
G26	Fuels for vehicles	144	12	3	70	18	32	8	8	2	6022	8588	8864	-2639	-8770	12065
G27	Other fuels for heating	2	3	1		37	2	1	1		899	126	2354	-190	-38	3151
G28	Natural gas							2	2		11319		6391		-799	16911
G29	Distributed gas	42	66	19	5	863	48	12	12	4	3993	5255				9248
G30	Electricity	122	43	15	20	113	42	29	27	9	7792	3030	27			10849

Table V.4 continued

		B1 Dairy farming	B2 Pig farming	B3 Poultry farming	B4 Arable farming	B5 Hort. glass	B6 Hort. Other.	B9 Beef industry	B10 Pig meat industry	B11 Poultry meat industry	Total inter-mediate use	Cons.+ Invest.	Exports	Margins	Taxes/ Subsidies	Total
G31	Water	69	24	8	11	64	24	2	2		728	1588				2316
G32	Fertiliser	316	5		173	15	12				724	91	1381	-342	-1	1853
G33	Other chemical products	54	8	2	13	9	11	20	18	6	27755	11046	35883	-11141	-320	63223
G34	Pesticides	31	3	1	145	39	75				528	69	647	-175	-3	1066
G35	Rubber and synthetics										721	5	771	-117	-1	1379
G36	Semi-manufact. metal products	12						1	1	1	17228	498	11500	-3870	-43	25313
G37	Metal products and machinery	16	2	1	4	2	3	8	8	3	26969	24881	39921	-13700	-728	77343
G38	Transport equipment and parts										8453	20699	14053	-4877	-3501	34827
G39	Furniture, electr., packing etc.				7	140	85	148	137	45	24885	35424	26957	-18768	-352	68146
G40	Garden and agricultural services	980	66	16	433	246	139	1			3010	254				3264
G41	Construction and ground work	247	66	16	13	50	24	12	12	4	33836	48054	1800			83690
G42	Transport services	2						4	3	1	5193	6842	23248		3602	38885
G43	Cleaning services	18	3	1	5	3	3	11	10	3	1951	1627				3578
G44	Other services	1610	248	61	352	528	440	345	321	104	183676	263161	33066		2285	482188
G45	Trade and transport margins													108229		108229
Total intermediate use		7867	4813	2023	1480	2685	1278	5882	6477	2219	**501332**	**511592**	**293180**	**0**	**-11329**	**1294775**
Non product related taxes/subsidies		348	52	12	84	53	73	83	91	34	**14005**					
Wages/social premiums hired labour		193	57	51	104	1397	623	548	514	253	**308769**					
Self employed factor income		2459	385	246	963	3010	2061				**9124**					
Capital income		1800	339	83	310	565	524	65	171	169	**204043**					
TOTAL USE		12667	5646	2415	2941	7710	4559	6578	7253	2675	**1037273**					

[a] Million 1993 guilders in buyers' prices

Sources: CBS-2 (1996), CBS-3 (1996) and own calculations

Appendix VI Margin and tax tables

Table VI.1 *Margin and tax table 1990*[a]

		Market margins				Taxes/subsidies[b]		
		Export	Domestic use	Consumption	TOTAL	Export	Domestic use	TOTAL
G1	Cattle	-52	-717	0	-769	0	17	17
G2	Pigs	-50	-334	0	-384	0	0	0
G3	Poultry	-27	-153	0	-180	0	3	3
G4	Flowers and plants	-502	-888	-720	-2110	0	-73	-73
G5	Grain	-28	-200	0	-228	0	-35	-35
G6	Arable products n.e.c.	-293	-1295	-136	-1724	0	-52	-52
G7	Milk	0	0	0	0	0	0	0
G8	Vegetables/fruits	-917	-1195	-933	-3045	0	-102	-102
G9	Oils and fat	-79	-172	-121	-372	0	-37	-37
G10	Starch	-174	-90	0	-264	112	0	112
G11	Compound feed	-43	-406	0	-449	0	45	45
G12	Dairy products	-415	-437	-1182	-2034	1196	349	1545
G13	Eggs	-196	-96	-80	-372	37	-2	35
G14	Fish and fish products	-285	-359	-301	-945	0	-38	-38
G15	Beef and other meat	-147	-340	-1310	-1797	151	-39	112
G16	Pig meat	-273	-439	-1035	-1747	37	-1	36
G17	Poultry meat	-16	-23	-286	-325	16	-19	-3
G18	Sugar	-40	-154	-60	-254	159	-43	116
G19	Food products n.e.c.	-776	-1838	-2965	-5579	270	-224	46
G20	Beverages and tobacco	-427	-1043	-1318	-2788	39	-4260	-4221
G21	Raw mat.leather/textiles/paper	-1309	-3466	-8227	-13002	0	-153	-153
G22	Other minerals	-104	-857	-22	-983	0	0	0
G23	Building materials	-433	-3871	-574	-4878	0	-25	-25
G24	Coal	-10	-161	0	-171	0	-140	-140
G25	Other raw materials energy	-50	-591	-10	-651	0	-5	-5
G26	Fuels for vehicles	-482	-1148	-520	-2150	0	-5909	-5909
G27	Other fuels for heating	-112	-82	-3	-197	0	-42	-42
G28	Natural gas	0	0	0	0	0	-184	-184
G29	Distributed gas	0	0	0	0	0	0	0
G30	Electricity	0	0	0	0	0	0	0

Table VI.1 continued

		Market margins				Taxes/subsidies[b]		
		Export	Domestic use	Consumption	TOTAL	Export	Domestic use.	TOTAL
G31	Water	0	0	0	0	0	0	0
G32	Fertiliser	-174	-193	-36	-403	0	-1	-1
G33	Other chemical products	-1982	-4391	-3480	-9853	10	-298	-288
G34	Pesticides	-60	-85	-23	-168	0	-2	-2
G35	Rubber and synthetics	-64	-55	-4	-123	0	-1	-1
G36	Semi-manufact. metal products	-933	-3097	-11	-4041	0	-44	-44
G37	Metal products and machinery	-2919	-9653	-170	-12742	0	-619	-619
G38	Transport equipment and parts	-381	-3424	-1156	-4961	0	-2935	-2935
G39	Furniture, electr., packing etc.	-1975	-7575	-7686	-17236	0	-369	-369
G40	Garden and agricultural services	0	0	0	0	0	0	0
G41	Construction and ground work	0	0	0	0	0	0	0
G42	Transport services	0	0	0	0	120	3484	3604
G43	Cleaning services	0	0	0	0	0	0	0
G44	Other services	0	0	0	0	0	2255	2255
G45	Trade and transport margins	0	0	0	0	0	0	0
TOTAL		-15728	-48828	-32369	-96925	2147	-9499	-7352

[a] Million 1990 guilders

[b] Negative numbers are taxes, positive numbers are subsidies

Source: CBS-2 (1993), CBS-3 (1993) and own calculations

Table VI.2 *Margin and tax table 1993*[a]

		Market margins				Taxes/subsidies[b]			
		Export	Domestic use	Consumption	TOTAL	Export	Domestic use	Import	TOTAL
G1	Cattle	-67	-817	0	-884	22	0	0	22
G2	Pigs	-75	-437	0	-512	0	0	0	0
G3	Poultry	-30	-196	0	-226	4	0	0	4
G4	Flowers and plants	-598	-1046	-823	-2467	0	0	-92	-92
G5	Grain	-50	-186	0	-236	126	0	-27	99
G6	Arable products n.e.c.	-322	-1262	-134	-1718	29	0	-26	3
G7	Milk	0	0	0	0	0	0	0	0
G8	Vegetables/fruits	- 1183	-1383	-1088	-3654	68	0	-166	-98
G9	Oils and fat	-114	-215	-158	-487	0	0	-30	-30
G10	Starch	- 195	-109	0	-304	168	0	0	168
G11	Compound feed	-68	-459	0	-527	19	0	0	19
G12	Dairy products	- 490	-495	-1373	-2358	2029	60	-50	2039
G13	Eggs	- 188	-118	-93	-399	50	0	-6	44
G14	Fish and fish products	- 298	-403	-354	-1055	0	0	-42	-42
G15	Beef and other meat	- 195	-396	-1489	-2080	476	0	-38	438
G16	Pig meat	-268	-592	-1410	-2270	48	0	-2	46
G17	Poultry meat	- 29	-38	-409	-476	62	0	-34	28
G18	Sugar	- 30	-171	-68	-269	133	26	-3	156
G19	Food products n.e.c.	-919	-2092	-3543	-6554	401	0	-198	203
G20	Beverages and tobacco	-542	-1290	-1616	-3448	32	-5157	0	-5125
G21	Raw mat.leather/textiles/paper	-1453	-3882	-9825	-15160	3	0	-213	-210
G22	Other minerals	-111	-880	-30	-1021	0	0	0	0
G23	Building materials	-494	-4193	-697	-5384	0	0	-23	-23
G24	Coal	-12	-157	0	-169	0	-302	0	-302
G25	Other raw materials energy	-63	-673	-16	-752	0	-7	0	-7
G26	Fuels for vehicles	-443	-1542	-654	-2639	0	-8770	0	-8770
G27	Other fuels for heating	-97	-90	-3	-190	0	-38	0	-38
G28	Natural gas	0	0	0	0	0	-799	0	-799
G29	Distributed gas	0	0	0	0	0	0	0	0
G30	Electricity	0	0	0	0	0	0	0	0

Table VI.2 continued

		Market margins				Taxes/subsidies[b]			
		Export	Domestic use	Consumption	TOTAL	Export	Domestic use.	Import	TOTAL
G31	Water	0	0	0	0	0	0	0	0
G32	Fertiliser	-136	-164	-42	-342	0	0	-1	-1
G33	Other chemical products	-1934	-4689	-4518	-11141	19	-14	-325	-320
G34	Pesticides	-64	-86	-25	-175	0	0	-3	-3
G35	Rubber and synthetics	-57	-55	-5	-117	0	0	-1	-1
G36	Semi-manufact. metal products	-931	-2926	-13	-3870	0	0	-43	-43
G37	Metal products and machinery	-3467	-10051	-182	-13700	0	0	-728	-728
G38	Transport equipment and parts	-403	-3234	-1240	-4877	0	-3214	-287	-3501
G39	Furniture, electr., packing etc.	-2217	-7867	-8684	-18768	0	0	-352	-352
G40	Garden and agricultural services	0	0	0	0	0	0	0	0
G41	Construction and ground work	0	0	0	0	0	0	0	0
G42	Transport services	0	0	0	0	96	3506	0	3602
G43	Cleaning services	0	0	0	0	0	0	0	0
G44	Other services	0	0	0	0	0	2285	0	2285
G45	Trade and transport margins	0	0	0	0	0	0	0	0
TOTAL		-17543	-52194	-38492	-108229	3785	-12424	-2690	-11329

[a] Million 1993 guilders

[b] Negative numbers are taxes, positive numbers are subsidies

Source: CBS-2 (1996), CBS-3 (1996) and own calculations

Appendix VII Emission tables

Table VII.1 *CO_2 emissions in 1990 for industries and consumption, distributed by economic variable*[a]

Emissions related to:	Output	Fuels for vehicles	Coal	Other fuels for heating	Natural gas	Distributed gas	TOTAL
Dairy farming	294	321	0	18	0	187	820
Pig farming	204	25	0	18	0	216	463
Poultry farming	102	8	0	9	0	62	181
Arable farming	0	175	0	0	0	29	204
Horticulture under glass	0	35	0	323	0	6352	6710
Other horticulture	0	68	0	18	0	207	293
Forestry and agricultural services	0	238	0	0	0	21	259
Fishery	0	0	0	290	0	0	290
Beef and other meat industry	0	20	0	9	7	68	104
Pig meat industry	0	26	0	9	14	90	139
Poultry meat industry	0	6	0	0	7	21	34
Dairy products manufacturing	0	41	0	8	512	266	827
Compound feed industry	0	8	0	17	0	153	178
Sugar industry	0	0	226	0	509	21	756
Margarine industry	0	10	0	0	172	143	325
Starch industry	0	0	0	8	465	14	487
Other food products manufacturing	279	100	0	59	218	994	1650
Oil and gas extraction	0	13	0	0	1407	0	1420
Other mining industries	0	0	0	168	142	0	310
Clothing/wood/paper industry	11	132	0	67	1388	382	1980
Petroleum industry	476	78	0	8598	1120	108	10380
Fertilizer industry	143	0	0	133	2774	3	3053
Chemical pesticides manufacturing	40	6	0	0	7	10	63
Other chemical industries	2650	275	1033	3292	5762	322	13334
Synthetics and building mat. industry	822	87	83	482	859	597	2930
Basic metal industry	948	54	0	1158	2542	298	5000
Machinery/metal products manufacturing	51	207	0	158	0	1064	1480
Transport equipment industry	23	67	0	50	0	23	163
Electrical products and other industries	87	117	0	0	17	396	617
Electricity supply	0	144	23015	391	14697	23	38270
Gas distribution	0	5	0	0	50	0	55
Water supply	0	15	0	0	0	110	125
Construction	218	1272	0	153	22	155	1820
Wholesale and retail trade	5	473	0	0	0	611	1089
Transport and storage industry	7	7713	0	395	0	1455	9570
Environmental cleaning	3089	303	0	0	0	308	3700
Other services	44	2394	0	722	0	6481	9641
SUBTOTAL	9493	14726	24357	16263	32691	21190	118720
Consumption	1600[b]	13740	61	745	0	18424	34570
TOTAL	11093	28466	24418	17008	32691	39614	153290

[a] CO_2 emissions in million kg

[b] Emissions related to aggregate consumption

Source: CBS-6 (1996), CBS-7 (1992), CBS-8 (1993) and own calculations

Table VII.2 *NO_x emissions in 1990 for industries and consumption, distributed by economic variable*[a]

Emissions related to:	Output	Fuels for vehicles	Coal	Other fuels for heating	Natural gas	Distributed gas	TOTAL
Dairy farming	0	5	0	0	0	0	5
Pig farming	0	0	0	0	0	0	0
Poultry farming	0	0	0	0	0	0	0
Arable farming	0	3	0	0	0	0	3
Horticulture under glass	0	1	0	0	0	8	9
Other horticulture	0	1	0	0	0	0	1
Forestry and agricultural services	0	4	0	0	0	0	4
Fishery	0	0	0	4	0	0	4
Beef and other meat industry	0	0	0	0	0	0	0
Pig meat industry	0	1	0	0	0	0	1
Poultry meat industry	0	0	0	0	0	0	0
Dairy products manufacturing	0	0	0	0	1	1	2
Compound feed industry	0	0	0	0	0	0	0
Sugar industry	0	0	0	0	2	0	2
Margarine industry	0	0	0	0	1	0	1
Starch industry	0	0	0	0	1	0	1
Other food products manufacturing	0	1	0	0	0	2	3
Oil and gas extraction	0	0	0	0	5	0	5
Other mining industries	0	0	0	0	0	0	0
Clothing/wood/paper industry	0	2	0	0	3	1	6
Petroleum industry	0	1	0	21	0	0	22
Fertilizer industry	0	0	0	0	5	0	5
Chemical pesticides manufacturing	0	0	0	0	0	0	0
Other chemical industries	17	4	2	6	13	1	43
Synthetics and building material industry	0	1	0	4	6	2	13
Basic metal industry	1	1	0	8	2	0	12
Machinery/metal products manufacturing	0	3	0	0	0	1	4
Transport equipment industry	0	1	0	0	0	0	1
Electrical products and other industries	0	1	0	0	0	1	2
Electricity supply	0	2	49	1	23	0	75
Gas distribution	0	0	0	0	0	0	0
Water supply	0	0	0	0	0	1	1
Construction	0	14	0	0	0	0	14
Wholesale and retail trade	0	5	0	0	0	0	5
Transport and storage industry	0	108	0	0	0	2	110
Environmental cleaning	5	4	0	0	0	0	9
Other services	0	27	0	1	0	6	34
SUBTOTAL	23	194	51	41	62	26	397
Consumption	2[b]	156	0	1	0	18	177
TOTAL	25	350	51	42	62	44	574

[a] NO_x emissions in million kg

[b] Emissions related to aggregate consumption

Source: CBS-6 (1996), CBS-7 (1992), CBS-8 (1993) and own calculations

Table VII.3 *SO_2 emissions in 1990 for industries and consumption, distributed by economic variable*[a]

Emissions related to:	Output	Fuels for vehicles	Coal	Other fuels for heating	Natural gas	Distributed gas	TOTAL
Dairy farming	0	1	0	0	0	0	1
Pig farming	0	0	0	0	0	0	0
Poultry farming	0	0	0	0	0	0	0
Arable farming	0	0	0	0	0	0	0
Horticulture under glass	0	0	0	1	0	0	1
Other horticulture	0	0	0	0	0	0	0
Forestry and agricultural services	0	0	0	0	0	0	0
Fishery	0	0	0	0	0	0	0
Beef and other meat industry	0	0	0	0	0	0	0
Pig meat industry	0	0	0	0	0	0	0
Poultry meat industry	0	0	0	0	0	0	0
Dairy products manufacturing	0	0	0	0	0	0	0
Compound feed industry	0	0	0	0	0	0	0
Sugar industry	0	0	1	0	0	0	1
Margarine industry	0	0	0	0	0	0	0
Starch industry	0	0	0	0	0	0	0
Other food products manufacturing	0	0	0	1	0	0	1
Oil and gas extraction	0	0	0	0	2	0	2
Other mining industries	0	0	0	0	0	0	0
Clothing/wood/paper industry	0	0	0	0	0	0	0
Petroleum industry	10	0	0	61	0	0	71
Fertilizer industry	0	0	0	1	0	0	1
Chemical pesticides manufacturing	0	0	0	0	0	0	0
Other chemical industries	11	0	3	9	0	0	23
Synthetics and building material industry	3	0	1	2	0	0	6
Basic metal industry	10	0	0	4	0	0	14
Machinery/metal products manufacturing	1	0	0	0	0	0	1
Transport equipment industry	0	0	0	0	0	0	0
Electrical products and other industries	1	0	0	0	0	0	1
Electricity supply	0	0	45	2	0	0	47
Gas distribution	0	0	0	0	0	0	0
Water supply	0	0	0	0	0	0	0
Construction	0	1	0	0	0	0	1
Wholesale and retail trade	0	0	0	0	0	0	0
Transport and storage industry	0	16	0	1	0	0	17
Environmental cleaning	3	1	0	0	0	0	4
Other services	0	2	0	3	0	0	5
SUBTOTAL	39	21	50	85	2	0	197
Consumption	0	4	0	1	0	0	5
TOTAL	39	25	50	86	2	0	202

[a] SO_2 emissions in million kg

Source: CBS-6 (1996), CBS-7 (1992), CBS-8 (1993) and own calculations

Table VII.4 *N and P emissions in 1990 for industries and consumption, distributed by economic variable*[a]

	N emissions					P emissions			
Emissions related to:	Output	Fertiliser	Other chemical products	Indirect to NO_x, N_2O and NH_3	TOTAL	Output	Fertiliser	Other chemical products	TOTAL
Dairy farming	27	0	0	99	126	3	0	0	3
Pig farming	396	0	0	62	458	44	0	0	44
Poultry farming	260	0	0	30	290	28	0	0	28
Arable farming	0	138	0	20	158	0	37	0	37
Horticulture under glass	0	99	0	3	102	0	12	0	12
Other horticulture	0	61	0	0	61	0	8	0	8
Forestry and agricultural services	0	0	0	1	1	0	0	0	0
Fishery	0	0	0	1	1	0	0	0	0
Beef and other meat industry	1	0	0	0	1	0	0	0	0
Pig meat industry	2	0	0	0	2	1	0	0	1
Poultry meat industry	1	0	0	0	1	0	0	0	0
Dairy products manufacturing	4	0	0	1	5	1	0	0	1
Compound feed industry	0	0	0	0	0	0	0	0	0
Sugar industry	0	0	0	1	1	0	0	0	0
Margarine industry	1	0	0	0	1	0	0	0	0
Starch industry	9	0	0	0	9	4	0	0	4
Other food products manufacturing	8	0	0	1	9	3	0	0	3
Oil and gas extraction	0	0	0	1	1	0	0	0	0
Other mining industries	0	0	0	0	0	0	0	0	0
Clothing/wood/paper industry	4	0	0	2	6	3	0	0	3
Petroleum industry	0	0	0	7	7	0	0	0	0
Fertilizer industry	0	0	0	2	2	3	0	0	3
Chemical pesticides manufacturing	0	0	0	0	0	0	0	0	0
Other chemical industries	0	0	0	18	18	2	0	0	2
Synthetics and building materials industry	0	0	0	4	4	0	0	0	0
Basic metal industry	0	0	0	5	5	0	0	0	0
Machinery/metal products manufacturing	1	0	0	1	2	0	0	0	0
Transport equipment industry	0	0	0	0	0	0	0	0	0
Electrical products and other industries	0	0	0	1	1	0	0	0	0
Electricity supply	0	0	0	23	23	0	0	0	0
Gas distribution	0	0	0	0	0	0	0	0	0
Water supply	0	0	0	0	0	0	0	0	0
Construction	1	0	0	4	5	0	0	0	0
Wholesale and retail trade	0	0	0	2	2	1	0	0	1
Transport and storage industry	0	0	0	33	33	0	0	0	0
Environmental cleaning	49	0	0	4	53	19	0	0	19
Other services	6	0	0	11	17	6	0	0	6
SUBTOTAL	770	298	0	337	1405	118	57	0	175
Consumption	0	0	60	66	126	0	0	14	14
TOTAL	770	298	60	403	1531	118	57	14	189

[a] N and P emissions in million kg

Source: CBS-6 (1996), CBS-9 (various years), CBS-10 (various years), CBS-11 (1997), CBS-12 (various years), CBS-13 (1992) and own calculations

Table VII.5 *Miscellaneous emissions in 1990 related to output industries and total consumption*[a]

Emissions related to output:	N_2O	CH_4	NH_3	Waste
Dairy farming	16	250	106	205
Pig farming	1	174	74	124
Poultry farming	0	87	37	41
Arable farming	10	0	16	92
Horticulture under glass	0	0	0	165
Other horticulture	0	0	0	104
Forestry and agricultural services	0	0	0	37
Fishery	0	0	0	172
Beef and other meat industry	0	0	0	106
Pig meat industry	0	0	0	170
Poultry meat industry	0	0	0	43
Dairy products manufacturing	0	0	0	281
Compound feed industry	0	0	0	192
Sugar industry	0	0	0	38
Margarine industry	0	0	0	90
Starch industry	0	0	0	38
Other food products manufacturing	0	0	0	652
Oil and gas extraction	0	80	0	20
Other mining industries	0	0	0	140
Clothing/wood/paper industry	0	0	0	730
Petroleum industry	0	0	0	50
Fertilizer industry	1	0	0	157
Chemical pesticides manufacturing	0	0	0	45
Other chemical industries	9	3	3	2918
Synthetics and building material industry	0	0	0	490
Basic metal industry	1	0	0	160
Machinery/metal products manufacturing	0	0	0	230
Transport equipment industry	0	0	0	77
Electrical products and other industries	0	0	0	153
Electricity supply	0	0	0	580
Gas distribution	0	72	0	24
Water supply	0	0	0	6
Construction	0	0	0	4920
Wholesale and retail trade	0	0	0	503
Transport and storage industry	2	1	0	310
Environmental cleaning	1	4	0	990
Other services	1	3	0	2047
SUBTOTAL	42	674	236	17100
Consumption	7	14	11	6440
TOTAL	49	688	247	23540

[a] N_2O, CH_4, NH_3 and waste emissions in million kg
Source: CBS-6 (1996), CBS-8 (1993) and own calculations

Table VII.6 *CO_2 emissions in 1993 for industries and consumption, distributed by economic variable*[a]

Emissions related to:	Output	Fuels for vehicles	Coal	Other fuels for heating	Natural gas	Distributed gas	TOTAL
Dairy farming	395.9	336.1	0.0	22.7	0.0	185.5	940.2
Pig farming	138.4	28.0	0.0	34.0	0.0	291.5	491.9
Poultry farming	65.7	7.0	0.0	11.3	0.0	83.9	167.9
Arable farming	0.0	163.4	0.0	0.0	0.0	22.1	185.5
Horticulture under glass	0.0	42.0	0.0	419.8	0.0	7622.2	8084.1
Other horticulture	0.0	74.7	0.0	22.7	0.0	212.0	309.4
Forestry and agricultural services	0.0	261.4	0.0	0.0	0.0	26.5	287.9
Fishery	0.0	324.4	0.0	0.0	0.0	0.0	324.4
Beef and other meat industry	0.0	20.8	0.0	16.9	22.7	68.2	128.7
Pig meat industry	0.0	20.8	0.0	16.9	22.7	68.2	128.7
Poultry meat industry	0.0	5.2	0.0	0.0	0.0	22.7	27.9
Dairy products manufacturing	0.0	41.6	0.0	0.0	602.6	295.6	939.8
Compound feed industry	0.0	44.2	41.3	16.9	91.0	142.1	335.6
Sugar industry	245.6	2.6	206.7	0.0	534.4	39.8	1029.1
Margarine industry	0.0	18.2	0.0	0.0	181.9	176.2	376.4
Starch industry	0.0	2.6	0.0	16.9	477.5	22.7	519.8
Other food products manufacturing	0.0	137.9	0.0	118.6	91.0	1171.1	1518.6
Oil and gas extraction	2.0	60.8	0.0	0.0	1653.7	1.7	1718.1
Other mining industries	0.0	32.8	0.0	95.9	264.1	0.0	392.8
Clothing/wood/paper industry	8.5	223.5	16.0	41.1	1550.0	516.7	2355.8
Petroleum industry	536.8	113.9	0.0	9028.9	1200.7	95.4	10975.7
Fertilizer industry	1279.6	9.5	0.0	112.7	2119.8	2.1	3523.6
Chemical pesticides manufacturing	0.0	9.5	0.0	59.2	12.5	3.1	84.3
Other chemical industries	1748.4	350.1	587.1	4560.5	4844.6	218.5	12309.2
Synthetics and building material industry	1092.2	124.5	104.2	400.7	1079.7	591.9	3393.2
Basic metal industry	910.0	52.3	0.0	2637.6	1351.9	162.6	5114.4
Machinery/metal products manufacturing	52.0	263.6	0.0	93.3	14.6	1113.1	1536.6
Transport equipment industry	26.3	60.3	0.0	61.8	0.0	150.8	299.3
Electrical products and other industries	45.7	158.0	0.0	0.0	6.9	380.5	591.1
Electricity supply	0.0	130.5	20672.9	2055.7	15766.2	23.3	38648.6
Gas distribution	0.0	3.7	0.0	0.0	146.3	0.0	150.0
Water supply	0.0	11.2	0.0	0.0	0.0	330.7	341.9
Construction	250.4	1374.0	0.0	39.6	41.9	86.5	1792.5
Wholesale and retail trade	11.8	703.9	0.0	0.0	0.0	1612.9	2328.6
Transport and storage industry	8.0	8353.9	0.0	1342.0	0.0	862.7	10566.6
Environmental cleaning	2470.0	314.3	0.0	0.0	0.0	360.0	3144.3
Other services	43.8	2417.6	0.0	1119.4	0.0	6391.8	9972.5
SUBTOTAL	9331.1	16298.8	21628.3	22345.3	32076.7	23354.6	125034.8
Consumption	1600.0[b]	13962.2	57.6	652.5	0.0	19932.9	36205.2
TOTAL	10931.1	30261.0	21685.9	22997.8	32076.7	43287.5	161240.0

[a] CO_2 emissions in million kg

[b] Emissions related to aggregate consumption

Source: CBS-1 (1996), CBS-7 (1992), CBS-8 (1993) and own calculations

Table VII.7 *NO_x emissions in 1993 for industries and consumption, distributed by economic variable*[a]

Emissions related to:	Output	Fuels for vehicles	Coal	Other fuels for heating	Natural gas	Distributed gas	TOTAL
Dairy farming	0.0	4947.2	0.0	18.9	0.0	217.5	5183.7
Pig farming	0.0	412.3	0.0	28.4	0.0	341.9	782.5
Poultry farming	0.0	103.1	0.0	9.5	0.0	98.4	210.9
Arable farming	0.0	2404.9	0.0	0.0	0.0	25.9	2430.8
Horticulture under glass	0.0	618.4	0.0	349.9	0.0	8939.9	9908.2
Other horticulture	0.0	1099.4	0.0	18.9	0.0	248.6	1366.9
Forestry and agricultural services	0.0	3847.8	0.0	0.0	0.0	31.1	3878.9
Fishery	0.0	4775.4	0.0	0.0	0.0	0.0	4775.4
Beef and other meat industry	11.6	219.8	0.0	21.0	48.0	143.9	444.3
Pig meat industry	12.8	219.8	0.0	21.0	48.0	143.9	445.5
Poultry meat industry	4.7	55.0	0.0	0.0	0.0	48.0	107.6
Dairy products manufacturing	24.4	439.6	0.0	0.0	1270.7	623.4	2358.1
Compound feed industry	16.8	467.1	54.2	21.0	191.8	299.7	1050.6
Sugar industry	3.0	27.5	271.0	0.0	1126.8	83.9	1512.2
Margarine industry	8.2	192.3	0.0	0.0	383.6	371.6	955.7
Starch industry	3.2	27.5	0.0	21.0	1007.0	48.0	1106.6
Other food products manufacturing	57.4	1456.3	0.0	147.2	191.8	2469.5	4322.2
Oil and gas extraction	0.0	471.2	0.0	0.0	5578.4	5.6	6055.2
Other mining industries	0.0	346.5	0.0	71.4	236.6	0.0	654.5
Clothing/wood/paper industry	9.9	2454.5	25.0	21.0	3170.5	1056.8	6737.7
Petroleum industry	325.0	1520.2	0.0	20118.8	706.6	56.1	22726.7
Fertilizer industry	5696.1	118.1	0.0	130.2	3561.8	3.5	9509.7
Chemical pesticides manufacturing	0.0	118.1	0.0	99.1	31.6	7.9	256.7
Other chemical industries	2538.3	4367.9	1266.8	7627.4	12275.4	553.7	28629.5
Synthetics and building material industry	1556.8	1243.6	203.0	1451.1	6919.0	3793.3	15166.8
Basic metal industry	230.8	748.4	0.0	8199.0	2449.7	294.6	11922.4
Machinery/metal products manufacturing	255.2	2740.5	0.0	40.4	13.0	995.6	4044.6
Transport equipment industry	312.8	508.5	0.0	19.7	0.0	111.6	952.7
Electrical products and other industries	391.0	1331.8	0.0	0.0	5.1	281.6	2009.5
Electricity supply	0.0	1775.0	37739.5	386.0	21675.7	32.0	61608.3
Gas distribution	0.0	18.6	0.0	0.0	447.6	0.0	466.2
Water supply	0.0	55.8	0.0	0.0	0.0	232.4	288.2
Construction	742.2	9975.1	0.0	18.6	25.2	52.1	10813.2
Wholesale and retail trade	1.8	5993.9	0.0	0.0	0.0	1408.5	7404.2
Transport and storage industry	2.8	110099.4	0.0	1042.0	0.0	806.0	111950.3
Environmental cleaning	5197.8	3733.3	0.0	0.0	0.0	308.0	9239.1
Other services	6.6	20587.6	0.0	812.4	0.0	5581.8	26988.5
SUBTOTAL	17409.1	189521.4	39559.6	40693.9	61363.9	29716.2	378264.1
Consumption	2000.0[b]	147304.2	47.3	448.6	0.0	20471.2	170271.2
TOTAL	19409.1	336825.6	39606.8	41142.5	61363.9	50187.3	548535.3

[a] NO_x emissions in 1000 kg
[b] Emissions related to aggregate consumption
Source: CBS-1 (1996), CBS-7 (1992), CBS-8 (1993) and own calculations

Table VII.8 *SO_2 emissions in 1993 for industries and consumption, distributed by economic variable*[a]

Emissions related to:	Output	Fuels for vehicles	Coal	Other fuels for heating	Natural gas	Distributed gas	TOTAL
Dairy farming	0.0	339.3	0.0	18.4	0.0	0.5	358.3
Pig farming	0.0	28.3	0.0	27.6	0.0	0.9	56.8
Poultry farming	0.0	7.1	0.0	9.2	0.0	0.2	16.5
Arable farming	0.0	164.9	0.0	0.0	0.0	0.1	165.0
Horticulture under glass	0.0	42.4	0.0	341.0	0.0	22.4	405.8
Other horticulture	0.0	75.4	0.0	18.4	0.0	0.6	94.4
Forestry and agricultural services	0.0	263.9	0.0	0.0	0.0	0.1	264.0
Fishery	0.0	327.5	0.0	0.0	0.0	0.0	327.5
Beef and other meat industry	3.5	18.6	0.0	77.3	0.0	0.0	99.4
Pig meat industry	3.9	18.6	0.0	77.3	0.0	0.0	99.7
Poultry meat industry	1.4	4.6	0.0	0.0	0.0	0.0	6.1
Dairy products manufacturing	7.3	37.2	0.0	0.0	0.0	0.0	44.5
Compound feed industry	5.0	39.5	65.1	77.3	0.0	0.0	187.0
Sugar industry	0.9	2.3	325.7	0.0	0.0	0.0	329.0
Margarine industry	2.4	16.3	0.0	0.0	0.0	0.0	18.7
Starch industry	1.0	2.3	0.0	77.3	0.0	0.0	80.6
Other food products manufacturing	17.2	123.2	0.0	540.9	0.0	0.0	681.4
Oil and gas extraction	0.0	45.3	0.0	0.0	2155.6	2.2	2203.1
Other mining industries	0.0	31.2	0.0	118.4	1.4	0.0	150.9
Clothing/wood/paper industry	4.4	220.7	31.0	11.8	0.0	0.0	267.9
Petroleum industry	11285.4	110.1	0.0	63198.7	62.2	4.9	74661.4
Fertilizer industry	532.1	8.1	0.0	1034.8	0.0	0.0	1574.9
Chemical pesticides manufacturing	0.0	8.1	0.0	133.9	0.0	0.0	142.0
Other chemical industries	3433.2	298.7	1534.3	10313.2	3.4	0.2	15582.9
Synthetics and building material industry	4798.3	104.1	483.1	1506.2	0.0	0.0	6891.7
Basic metal industry	7116.5	56.4	0.0	3633.0	384.7	46.3	11236.9
Machinery/metal products manufacturing	214.5	230.0	0.0	82.2	0.0	0.0	526.7
Transport equipment industry	0.0	39.5	0.0	216.7	0.0	0.0	256.1
Electrical products and other industries	666.6	103.4	0.0	0.0	0.0	0.0	770.0
Electricity supply	0.0	133.6	25619.1	912.1	110.9	0.2	26775.8
Gas distribution	0.0	0.9	0.0	0.0	0.1	0.0	1.0
Water supply	0.0	2.7	0.0	0.0	0.0	32.7	35.4
Construction	129.1	953.9	0.0	210.0	0.9	1.9	1295.8
Wholesale and retail trade	17.4	484.4	0.0	0.0	0.0	14.1	515.9
Transport and storage industry	0.0	17478.1	0.0	716.6	0.0	1.9	18196.6
Environmental cleaning	3307.8	334.5	0.0	0.0	0.0	119.8	3762.1
Other services	64.2	1663.8	0.0	2326.9	0.0	55.9	4110.8
SUBTOTAL	31612.1	23818.7	28058.3	85679.3	2719.2	304.8	172192.4
Consumption	0.0	3815.4	248.8	517.6	0.0	104.4	4686.2
TOTAL	31612.1	27634.1	28307.1	86196.9	2719.2	409.1	176878.5

[a] SO_2 emissions in 1000 kg

Source: CBS-1 (1996), CBS-7 (1992), CBS-8 (1993) and own calculations

Table VII.9 *N_2O emissions in 1993 for industries and consumption, distributed by economic variable*[a]

Emissions related to:	Output	Fuels for vehicles	Coal	Other fuels for heating	Natural gas	Distributed gas	TOTAL
Dairy farming	16263.4	84.8	0.0	0.0	0.0	0.0	16348.2
Pig farming	565.2	7.1	0.0	0.0	0.0	0.0	572.3
Poultry farming	138.4	1.8	0.0	0.0	0.0	0.0	140.1
Arable farming	7235.7	41.2	0.0	0.0	0.0	0.0	7276.9
Horticulture under glass	130.6	10.6	0.0	0.0	0.0	0.0	141.2
Other horticulture	1275.6	18.8	0.0	0.0	0.0	0.0	1294.5
Forestry and agricultural services	0.0	65.9	0.0	0.0	0.0	0.0	65.9
Fishery	0.0	81.8	0.0	0.0	0.0	0.0	81.8
Beef and other meat industry	6.8	5.3	0.0	0.0	0.0	0.1	12.3
Pig meat industry	7.5	5.3	0.0	0.0	0.0	0.1	13.0
Poultry meat industry	2.8	1.3	0.0	0.0	0.0	0.0	4.1
Dairy products manufacturing	14.2	10.6	0.0	0.0	1.0	0.5	26.3
Compound feed industry	9.8	11.3	0.0	0.0	0.1	0.2	21.5
Sugar industry	1.7	0.7	0.2	0.0	0.9	0.1	3.5
Margarine industry	4.8	4.6	0.0	0.0	0.3	0.3	10.0
Starch industry	1.8	0.7	0.0	0.0	0.8	0.0	3.3
Other food products manufacturing	33.5	35.2	0.0	0.1	0.1	1.9	70.9
Oil and gas extraction	0.0	16.0	0.0	0.0	0.0	0.0	16.0
Other mining industries	0.0	8.0	0.0	0.0	0.0	0.0	8.0
Clothing/wood/paper industry	6.0	54.0	0.0	0.0	2.2	0.7	63.0
Petroleum industry	189.0	28.0	0.0	16.4	0.6	0.0	234.0
Fertilizer industry	2500.2	2.5	0.0	0.1	2.9	0.0	2505.8
Chemical pesticides manufacturing	0.0	2.5	0.0	0.1	0.0	0.0	2.6
Other chemical industries	7600.8	92.0	1.0	6.3	10.1	0.5	7710.6
Synthetics and building material industry	907.0	35.0	0.2	1.2	5.6	3.1	952.0
Basic metal industry	134.0	11.0	0.0	6.7	2.0	0.2	154.0
Machinery/metal products manufacturing	25.0	65.0	0.0	0.0	0.0	0.9	91.0
Transport equipment industry	182.2	19.9	0.0	0.0	0.0	0.0	202.1
Electrical products and other industries	227.8	52.1	0.0	0.0	0.0	0.0	279.9
Electricity supply	0.0	29.0	173.5	1.8	99.6	0.1	304.0
Gas distribution	0.0	2.0	0.0	0.0	0.0	0.0	2.0
Water supply	0.0	6.0	0.0	0.0	0.0	0.0	6.0
Construction	0.0	399.0	0.0	0.4	0.5	1.1	401.0
Wholesale and retail trade	3.8	221.4	0.0	0.0	0.0	31.2	256.5
Transport and storage industry	6.0	1605.0	0.0	23.1	0.0	17.9	1652.0
Environmental cleaning	529.0	64.0	0.0	0.0	0.0	7.0	600.0
Other services	14.2	760.6	0.0	18.0	0.0	123.8	916.5
SUBTOTAL	38017.0	3860.0	174.9	74.3	126.9	189.9	42443.0
Consumption	4216.0[b]	2720.0	1.0	9.9	0.0	454.0	7401.0
TOTAL	42233.0	6580.0	176.0	84.2	126.9	643.9	49844.0

[a] N_2O emissions in 1000 kg
[b] Emissions related to aggregate consumption
Source: CBS-1 (1995) and own calculations

Table VII.10 *CH_4 emissions in 1993 for industries and consumption, distributed by economic variable*[a]

	Output	Fuels for vehicles	Natural gas	Distributed gas	TOTAL
Dairy farming	294030.9	57.1	0.0	78.6	294166.6
Pig farming	102780.7	4.8	0.0	123.5	102909.0
Poultry farming	48788.3	1.2	0.0	35.6	48825.1
Arable farming	0.0	27.8	0.0	9.4	37.1
Horticulture under glass	0.0	7.1	0.0	3229.9	3237.1
Other horticulture	0.0	12.7	0.0	89.8	102.5
Forestry and agricultural services	0.0	44.4	0.0	11.2	55.6
Fishery	0.0	2.0	0.0	0.0	2.0
Beef and other meat industry	3.4	2.0	2.5	7.5	15.4
Pig meat industry	3.7	2.0	2.5	7.5	15.7
Poultry meat industry	1.4	0.5	0.0	2.5	4.4
Dairy products manufacturing	7.0	4.0	66.5	32.6	110.2
Compound feed industry	4.8	4.2	10.0	15.7	34.8
Sugar industry	0.9	0.2	59.0	4.4	64.5
Margarine industry	2.4	1.7	20.1	19.5	43.6
Starch industry	0.9	0.2	52.7	2.5	56.4
Other food products manufacturing	16.6	13.1	10.0	129.3	169.0
Oil and gas extraction	80200.0	6.0	1357.6	1.4	81565.0
Other mining industries	0.0	3.0	114.0	0.0	117.0
Clothing/wood/paper industry	2.0	20.0	86.3	28.8	137.0
Petroleum industry	219.0	14.0	239.9	19.1	492.0
Fertilizer industry	997.6	1.1	134.2	0.1	1133.1
Chemical pesticides manufacturing	0.0	1.1	0.8	0.2	2.1
Other chemical industries	3611.4	41.7	306.8	13.8	3973.8
Synthetics and building material industry	150.0	12.0	63.3	34.7	260.0
Basic metal industry	110.0	5.0	208.0	25.0	348.0
Machinery/metal products manufacturing	10.0	22.0	1.5	118.5	152.0
Transport equipment industry	10.2	6.1	0.0	6.7	23.0
Electrical products and other industries	17.8	15.9	0.3	17.0	51.0
Electricity supply	0.0	15.0	121.8	0.2	137.0
Gas distribution	79400.0	0.5	74.8	0.0	79475.3
Water supply	0.0	1.5	0.0	169.2	170.7
Construction	1.0	139.0	1.0	2.0	143.0
Wholesale and retail trade	528.0	69.9	0.0	580.5	1178.4
Transport and storage industry	1267.0	542.0	0.0	682.0	2491.0
Environmental cleaning	4205.0	26.0	0.0	114.0	4345.0
Other services	1953.0	240.1	0.0	2300.5	4493.6
SUBTOTAL	618323.0	1367.0	2933.9	7913.1	630537.0
Consumption	0.0	4773.0	0.0	8203.0	12976.0
TOTAL	618323.0	6140.0	2933.9	16116.1	643513.0

[a] CH_4 emissions in 1000 kg

Source: CBS-1 (1995) and own calculations

Table VII.11 *N and P emissions in 1993 for industries and consumption, distributed by economic variable*[a]

	N emissions				P emissions			
Emissions related to:	Output	Fertiliser	Indirect to NO_x and NH_3	TOTAL	Output	Fertiliser	Other chemical products	TOTAL
Dairy farming	146000.0	102000.0	106578.2	354578.2	22000.0	6000.0	0.0	28000.0
Pig farming	110000.0	4000.0	45238.2	159238.2	31000.0	0.0	0.0	31000.0
Poultry farming	48000.0	0.0	12064.2	60064.2	12000.0	0.0	0.0	12000.0
Arable farming	0.0	36000.0	2740.1	38740.1	-1000.0	0.0	0.0	-1000.0
Horticulture under glass	0.0	5000.0	3016.6	8016.6	0.0	0.0	0.0	0.0
Other horticulture	0.0	7000.0	416.2	7416.2	0.0	1000.0	0.0	1000.0
Forestry and agricultural services	0.0	0.0	1181.0	1181.0	0.0	0.0	0.0	0.0
Fishery	0.0	0.0	1453.9	1453.9	0.0	0.0	0.0	0.0
Beef and other meat industry	1979.5	0.0	198.1	2177.6	0.0	0.0	506.0	506.0
Pig meat industry	2182.6	0.0	204.9	2387.5	0.0	0.0	557.9	557.9
Poultry meat industry	805.0	0.0	58.3	863.3	0.0	0.0	205.8	205.8
Dairy products manufacturing	5490.5	0.0	849.4	6339.9	0.0	0.0	1403.5	1403.5
Compound feed industry	2597.6	0.0	410.5	3008.1	0.0	0.0	664.0	664.0
Sugar industry	413.9	0.0	476.4	890.4	0.0	0.0	105.8	105.8
Margarine industry	1022.6	0.0	335.0	1357.6	0.0	0.0	261.4	261.4
Starch industry	377.4	0.0	354.0	731.4	0.0	0.0	96.5	96.5
Other food products manufacturing	8833.9	0.0	1625.6	10459.5	0.0	0.0	2258.1	2258.1
Oil and gas extraction	5.0	0.0	1843.5	1848.5	0.0	0.0	4.0	4.0
Other mining industries	2.0	0.0	199.3	201.3	0.0	0.0	2.0	2.0
Clothing/wood/paper industry	5228.0	0.0	2104.8	7332.8	0.0	0.0	2521.0	2521.0
Petroleum industry	0.0	0.0	6925.9	6925.9	0.0	0.0	0.0	0.0
Fertilizer industry	479.4	0.0	5042.4	5521.8	0.0	0.0	2937.3	2937.3
Chemical pesticides manufacturing	0.0	0.0	78.1	78.1	0.0	0.0	0.0	0.0
Other chemical industries	2719.6	0.0	9487.4	12207.0	0.0	0.0	567.7	567.7
Synthetics and building materials industry	239.0	0.0	5054.4	5293.4	0.0	0.0	106.0	106.0
Basic metal industry	496.0	0.0	3821.5	4317.5	0.0	0.0	290.0	290.0
Machinery/metal products manufacturing	548.0	0.0	1248.7	1796.7	0.0	0.0	393.0	393.0
Transport equipment industry	0.0	0.0	290.0	290.0	0.0	0.0	0.0	0.0
Electrical products and other industries	401.0	0.0	952.3	1353.3	0.0	0.0	294.0	294.0
Electricity supply	90.0	0.0	18757.1	18847.1	0.0	0.0	39.0	39.0
Gas distribution	0.0	0.0	141.9	141.9	0.0	0.0	0.0	0.0
Water supply	22.0	0.0	87.7	109.7	0.0	0.0	17.0	17.0
Construction	196.0	0.0	3292.2	3488.2	0.0	0.0	151.0	151.0
Wholesale and retail trade	1895.6	0.0	2254.4	4150.0	0.0	0.0	1571.6	1571.6
Transport and storage industry	431.0	0.0	34085.7	34516.7	0.0	0.0	317.0	317.0
Environmental cleaning	57520.0	0.0	2817.0	60337.0	0.0	0.0	11589.0	11589.0
Other services	7011.4	0.0	8217.5	15228.9	0.0	0.0	5813.4	5813.4
SUBTOTAL	404987.0	154000.0	283902.5	842889.5	64000.0	7000.0	32672.0	103672.0
Consumption	72294.0[b]	0.0	60969.4	133263.4	0.0	0.0	13258.0	13258.0
TOTAL	477281.0	154000.0	344871.8	976152.8	64000.0	7000.0	45930.0	116930.0

a N and P emissions in 1000 kg

b Emissions related to aggregate consumption

Source: CBS-1 (1996), CBS-9 (various years), CBS-10 (various years), CBS-11 (1997), CBS-12 (various years), CBS-13 (1992), MVROM (1995) and own calculations

Table VII.12 *NH_3 and waste emissions in 1993 for industries and consumption, distributed by economic variable*[a]

	NH_3 emissions			Waste
Emissions related to:	Output	Fertiliser	Total	Output
Dairy farming	120373.1	7295.3	127668.4	218.7
Pig farming	54715.0	0.0	54715.0	97.5
Poultry farming	14590.7	0.0	14590.7	41.7
Arable farming	0.0	2431.8	2431.8	88.7
Horticulture under glass	0.0	0.0	0.0	163.9
Other horticulture	0.0	0.0	0.0	96.9
Forestry and agricultural services	0.0	0.0	0.0	35.9
Fishery	0.0	0.0	0.0	166.7
Beef and other meat industry	76.4	0.0	76.4	134.8
Pig meat industry	84.2	0.0	84.2	148.6
Poultry meat industry	31.1	0.0	31.1	54.8
Dairy products manufacturing	159.9	0.0	159.9	298.0
Compound feed industry	110.2	0.0	110.2	203.0
Sugar industry	19.5	0.0	19.5	40.3
Margarine industry	53.5	0.0	53.5	95.0
Starch industry	20.8	0.0	20.8	40.3
Other food products manufacturing	376.6	0.0	376.6	690.2
Oil and gas extraction	0.0	0.0	0.0	27.0
Other mining industries	0.0	0.0	0.0	97.0
Clothing/wood/paper industry	65.0	0.0	65.0	688.0
Petroleum industry	8.0	0.0	8.0	62.0
Fertilizer industry	2610.6	0.0	2610.6	81.5
Chemical pesticides manufacturing	0.0	0.0	0.0	31.0
Other chemical industries	937.4	0.0	937.4	1872.5
Synthetics and building material industry	531.0	0.0	531.0	423.0
Basic metal industry	233.0	0.0	233.0	164.0
Machinery/metal products manufacturing	21.0	0.0	21.0	212.0
Transport equipment industry	0.0	0.0	0.0	108.5
Electrical products and other industries	414.0	0.0	414.0	188.5
Electricity supply	0.0	0.0	0.0	208.0
Gas distribution	0.0	0.0	0.0	0.0
Water supply	0.0	0.0	0.0	54.0
Construction	0.0	0.0	0.0	4240.0
Wholesale and retail trade	0.2	0.0	0.2	588.0
Transport and storage industry	2.0	0.0	2.0	618.0
Environmental cleaning	5.0	0.0	5.0	1047.0
Other services	0.8	0.0	0.8	2175.0
SUBTOTAL	195438.8	9727.1	205165.9	15500.0
Consumption[b]	11100.0	0.0	11100.0	5845.0
TOTAL	206538.8	9727.1	216265.9	21345.0

[a] NH_3 emissions in 1000 kg; waste emissions in million kg

[b] Emissions related to aggregate consumption

Source: CBS-1 (1996), CBS-11 (1997), CBS-12 (various years), CBS-13 (1992), MVROM (1995) and own calculations

Appendix VIII Mineral balances Dutch agriculture

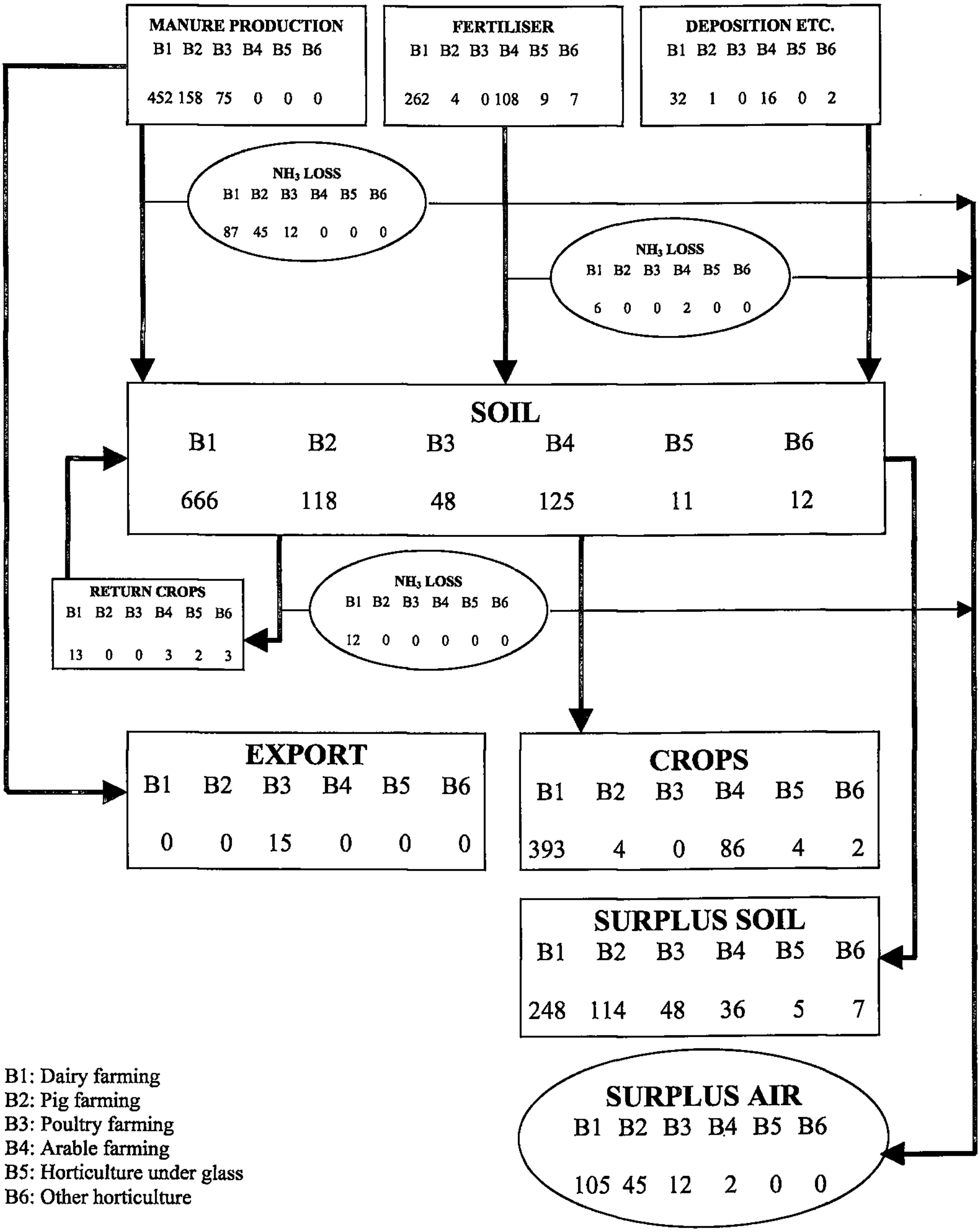
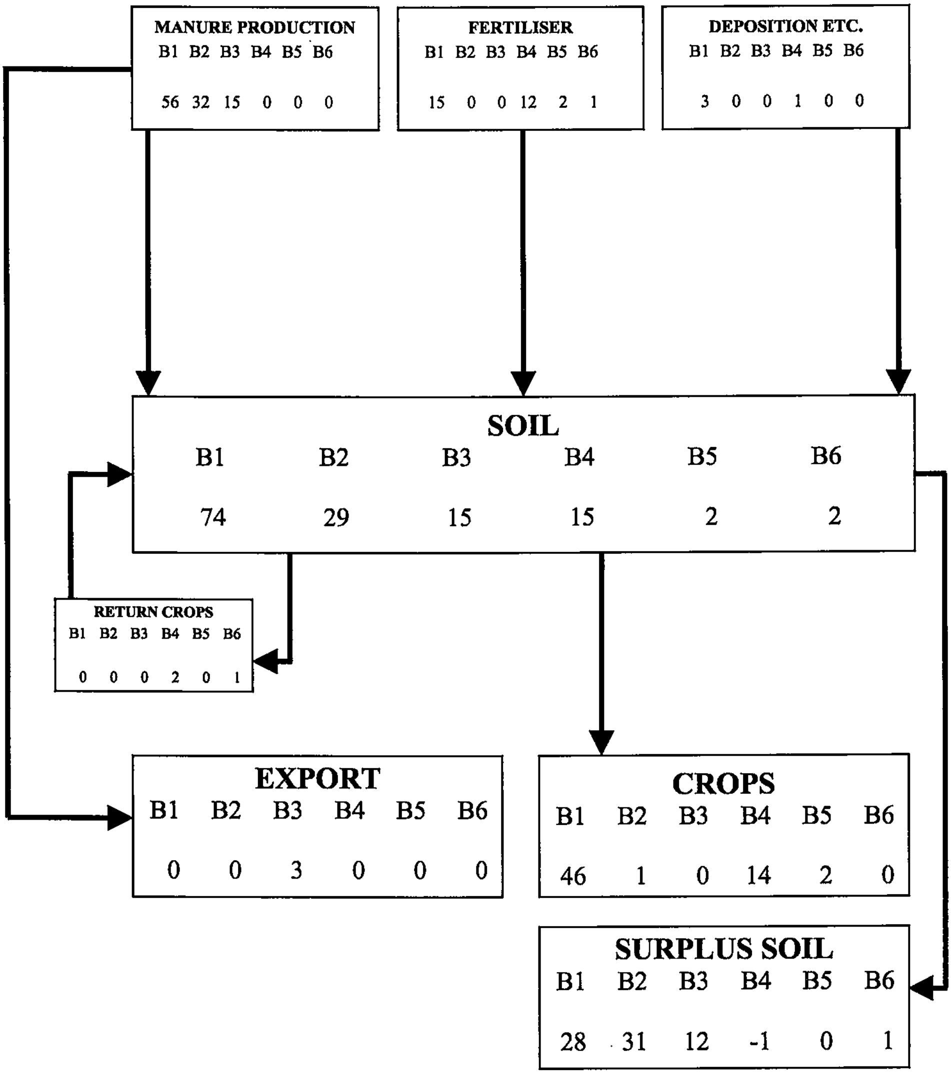


Figure VIII.1 *Nitrogen balance in 1993 for Dutch agriculture (in mln kg N)*

Sources: Own calculations and CBS-10 (1995), CBS-11 (1997), CBS-12 (1997), CBS-13 (1992), LEI/CBS (1994), LEI (1997) and MLNV (1995)



B1: Dairy farming
B2: Pig farming
B3: Poultry farming
B4: Arable farming
B5: Horticulture under glass
B6: Other horticulture

Figure VIII.2 *Phosphate balance in 1993 for Dutch agriculture (in mln kg P)*

Sources: Own calculations and CBS-10 (1995), CBS-11 (1997), CBS-12 (1997), CBS-13 (1992), LEI/CBS (1994), LE (1997) and MLNV (1995)

Appendix IX Elasticities

Table IX.1 *Substitution and transformation elasticities industries and commodities*[a]

Industry	CES between aggregate primary, aggregate energy and aggregate material input[b]	CES between labour and capital	CES between intermediate energy inputs and between intermediate material inputs[b]	Commodity	CES between domestic production and import	CET between domestic use and export
B1-B8	0.4	0.3	0.15	G1-G8*	4.5	-4.5
B9	0.6	0.3	0.3	G9	0.5	-0.5
B10	0.6	0.3	0.3	G10	0.5	-0.5
B11	0.6	0.3	0.3	G11	1.5	-1.5
B12	0.6	0.3	0.3	G12	2.0	-2.0
B13	0.4	0.2	0.2	G13	4.5	-4.5
B14	0.4	0.2	0.2	G14	1.15	-1.15
B15	0.7	0.4	0.3	G15-G17*	3.0	-3.0
B16	0.7	0.4	0.3	G18	1.15	-1.15
B17	0.7	0.4	0.3	G19	0.5	-0.5
B18	0.9	0.5	0.5	G20	1.5	-1.5
B19	2.0	0.8	1.3	G21	1.8	-1.8
B20	0.6	0.6	0.5	G22	2.0	-2.0
B21	0.9	0.5	0.5	G23	1.5	-1.5
B22	0.3	0.15	0.2	G24	4.0	-4.0
B23	0.3	0.15	0.2	G25	4.0	-4.0
B24	0.3	0.15	0.2	G26	2.5	-2.5
B25	0.7	0.4	0.3	G27	2.5	-2.5
B26	0.15	0.15	0.15	G28	4.0	-4.0
B27	0.7	0.4	0.2	G29	0.2	-0.2
B28	0.3	0.3	0.15	G30	2.0	-2.0
B29	0.6	0.15	0.6	G31	0.15	-0.15
B30	0.15	0.15	0.15	G32	2.0	-2.0
B31	0.15	0.15	0.15	G33	2.8	-2.8
B32	0.15	0.15	0.15	G34	2.0	-2.0
B33	1.15	0.7	0.3	G35	2.0	-2.0
B34	1.7	0.9	0.9	G36	1.5	-1.5
B35	0.7	0.4	0.3	G37	1.6	-1.6
B36	1.15	0.4	0.5	G38	1.7	-1.7
B37	1.15	0.4	0.5	G39	2.0	-2.0
				G40	0.15	-0.15
				G41	0.2	-0.2
				G42	0.2	-0.2
				G43	0.2	-0.2
				G44	0.25	-0.25
				G45	0.15	-0.15

[a] Most elasticities are calculated and adjusted from Zeelenberg et al. (1991). Elasticities denoted with * are based upon own approximations.

[b] Also valid in case intermediate energy and material inputs are nested in a single aggregate intermediate input (Chapter 3).

Table IX.2 *Miscellaneous elasticities*[a]

Transformation elasticity mobile labour distribution*	-0.5
Transformation elasticity capital distribution*	-0.6
Substitution elasticity mobile/immobile labour*	1.5
Substitution elasticity saving/current consumption*	1.15
Uncompensated labour supply elasticity*	0.1
Substitution elasticity private consumption	0.3
Substitution elasticity public consumption	0.2

[a] Elasticities are from Zeelenberg et al. (1991). Elasticities denoted with * are based upon own approximations.

Appendix X Effects on environmental indicators of energy taxes

Table X.1 *Effects on greenhouse gas emissions by industries and consumption of energy taxes (% change from benchmark)*

	Greenhouse gas excluding CFK's							
	CO_2		N_2O		CH_4		Total	
	Small	General	Small	General	Small	General	Small	General
Agriculture	0.2	-3.0	-0.1	-0.2	-0.2	-0.1	0.0	-1.3
Agribusiness	1.5	-5.4	-	-	-	-	1.5	-5.4
Other industries	-2.7	-6.0	0.3	-1.6	-0.9	-1.6	-2.5	-5.6
Public utilities	-4.7	-3.1	-	-	-6.0	-3.6	-4.7	-3.1
Services	-6.3	-2.8	-0.1	0.0	0.0	-0.1	-6.0	-2.7
Consumption	-2.9	-1.3	0.0	0.1	-5.2	-2.2	-2.7	-1.2
Waste dumping	-	-	-	-	0.0	-0.3	0.0	-0.3
TOTAL	-3.5	-3.5	0.0	-0.5	-0.6	-0.5	-3.1	-3.1

Table X.2 *Effects on acidification emissions by industries and consumption of energy taxes (% change from benchmark)*

	Acidification							
	NO_x		SO_2		NH_3		Total	
	Small	General	Small	General	Small	General	Small	General
Agriculture	0.4	-1.8	-0.9	-1.9	-0.2	-0.1	-0.2	-0.1
Agribusiness	1.0	-4.2	-1.2	-4.9	-	-	0.6	-4.3
Other industries	-1.9	-4.5	-6.6	-5.1	0.2	-0.8	-4.4	-4.7
Public utilities	-4.6	-3.0	-4.8	-3.2	-	-	-4.7	-3.1
Services	-0.9	-0.3	-2.1	-0.9	-	-	-1.1	-0.5
Consumption	-0.6	-0.4	-0.9	-0.5	0.0	0.1	-0.5	-0.3
TOTAL	-1.5	-1.8	-5.4	-4.0	-0.2	-0.1	-1.6	-1.5

Table X.3 *Effects on eutrophication emissions and waste by industries and consumption of energy taxes (% change from benchmark)*

	Eutrophication						Waste	
	N		P		Total			
	Small	General	Small	General	Small	General	Small	General
Agriculture	-0.2	-0.1	-0.2	-0.2	-0.2	-0.1	-0.1	-0.2
Agribusiness	0.3	-0.8	0.2	-0.3	0.2	-0.5	0.0	-0.1
Other industries	-1.5	-3.4	0.5	-4.3	-0.3	-4.0	0.2	-0.5
Public utilities	-4.7	-3.1	-	-	-4.7	-3.1	-4.3	-2.8
Services	-0.4	-0.2	0.0	-0.1	-0.2	-0.1	0.0	0.0
Consumption	-0.1	-0.1	0.2	0.0	0.1	-0.1	0.0	0.1
TOTAL	-0.3	-0.3	-0.1	-0.3	-0.2	-0.3	0.0	-0.3

Appendix XI Effects on emissions in agriculture of energy taxes

Table XI.1 *Effects on greenhouse gas emissions in agriculture of energy taxes (% change from benchmark)*

	Greenhouse gas excluding CFK's							
	CO_2		N_2O		CH_4		Total	
	Small	General	Small	General	Small	General	Small	General
Dairy farming	-1.5	-0.8	-0.1	-0.2	-0.1	-0.2	-0.3	-0.2
Pig farming	-3.5	-1.3	-0.3	-0.0	-0.3	-0.0	-0.9	-0.3
Poultry farming	-2.6	-0.9	-	-	-0.2	0.1	-0.6	-0.1
Arable farming	-0.9	-0.7	-0.1	-0.2	-	-	-0.1	-0.2
Horticulture under glass	1.0	-3.6	-	-	-	-	1.0	-3.6
Other horticulture	-5.1	-1.8	-	-	-	-	-5.1	-1.8
TOTAL	0.2	-3.0	-0.1	-0.2	-0.2	-0.1	0.0	-1.3

Table XI.2 *Effects on acidification emissions in agriculture of energy taxes (% change from benchmark)*

	Acidification							
	NO_x		SO_2		NH_3		Total	
	Small	General	Small	General	Small	General	Small	General
Dairy farming	-0.1	-0.3	-0.1	-0.3	-0.1	-0.2	-0.1	-0.2
Pig farming	-	-	-	-	-0.3	-0.0	-0.3	-0.0
Poultry farming	-	-	-	-	-0.2	0.1	-0.2	0.1
Arable farming	-0.1	-0.4	-	-	-0.1	-0.2	-0.1	-0.2
Horticulture under glass	1.0	-3.3	-1.8	-3.5	-	-	0.6	-3.3
Other horticulture	-0.4	0.2		-	-	-	-0.4	0.2
TOTAL	0.4	-1.8	-0.9	-1.9	-0.2	-0.1	-0.2	-0.1

Table XI.3 *Effects on eutrophication emissions and waste in agriculture of energy taxes (% change from benchmark)*

	Eutrophication						Waste	
	N		P		Total			
	Small	General	Small	General	Small	General	Small	General
Dairy farming	-0.1	-0.2	-0.1	-0.2	-0.1	-0.2	-0.1	-0.2
Pig farming	-0.3	-0.0	-0.3	-0.0	-0.3	-0.0	-0.3	-0.0
Poultry farming	-0.2	0.1	-0.2	0.1	-0.2	0.1	-0.2	0.1
Arable farming	-0.1	-0.4	-0.1	-0.4	-0.1	-0.4	-0.1	-0.2
Horticulture under glass	0.2	-0.8	0.1	-0.7	0.1	-0.7	0.2	-0.7
Other horticulture	-0.4	0.2	-0.4	0.2	-0.4	0.2	-0.3	0.1
TOTAL	-0.2	-0.1	-0.2	-0.2	-0.2	-0.1	-0.1	-0.2

Appendix XII Effects of restrictions on emissions: a partial analysis

To understand the results it is helpful to identify some of the main factors that determine the effects obtained in Chapter 5. The following partial analysis is restricted to the effects for the shadow price of an emission permit of emissions that are related to one input by a single industry. The level EN_g and change dEN_g of emissions related to an input g are (subscripts e and b are omitted for convenience):

$$EN_g = \psi_g^{IN}.IN_g \tag{XII.1}$$

$$dEN_g = \psi_g^{IN}.dIN_g \tag{XII.2}$$

Assuming perfectly elastic supply of inputs, a change of input can be written using the own price elasticity of input demand ε_w^{IN} :

$$dIN_g = \varepsilon_w^{IN}.dWIN_g.\frac{IN_g}{WIN_g} \tag{XII.3}$$

The price change is due to the restriction and, assuming perfectly elastic supply, can be calculated using the value of the rent which is equal to the total value of emission permits (XII.4):

$$dWIN_g = \frac{RENT_g^{IN}}{IN_g} = \frac{WEN_g.EN_g}{IN_g} \tag{XII.4}$$

Substituting (XII.4) and (XII.3) in (XII.2) gives:

$$dEN_g = \psi_g^{IN}.\varepsilon_{WIN_g}^{IN_g}.\frac{WEN_g}{WIN_g}.EN_g \tag{XII.5}$$

From (XII.5) the shadow price of an emission permit can be derived as:

$$WEN_g = \frac{dEN_g}{EN_g}.\frac{WIN_g}{\psi_g^{IN}.\varepsilon_{WIN_g}^{IN_g}} \tag{XII.6}$$

Assuming perfectly elastic supply of inputs, the following relation exists between the own price elasticity of input demand, the cost share of input (S_{IN}) and the Allen Partial Elasticity of Substitution between inputs (σ_{IN}) that is used in the model (see Berndt and Christensen, 1973, and applying Euler's Law):

$$\varepsilon_{WIN_g}^{IN_g} = (S_{IN_g} - 1).\sigma_{IN} \tag{XII.7}$$

Finally, substituting (XII.7) in (XII.6) we have:

$$WEN_g = \widetilde{EN}.\frac{WIN_g}{\psi_g^{IN}.(S_{IN_g} - 1).\sigma_{IN}} \tag{XII.8}$$

where $\widetilde{EN}$ is relative environmental indicator reduction.

Since σ_{IN} is positive, from this it can be concluded that the shadow price of an emission permit related to a specific input as result of an emission reduction, is lower:

* the smaller is the cost share of the input to which emissions are related;
* the greater is the substitution elasticity between inputs;
* the greater is the emission coefficient;
* the smaller is the reduction.

Appendix XIII Welfare costs of reducing environmental indicators

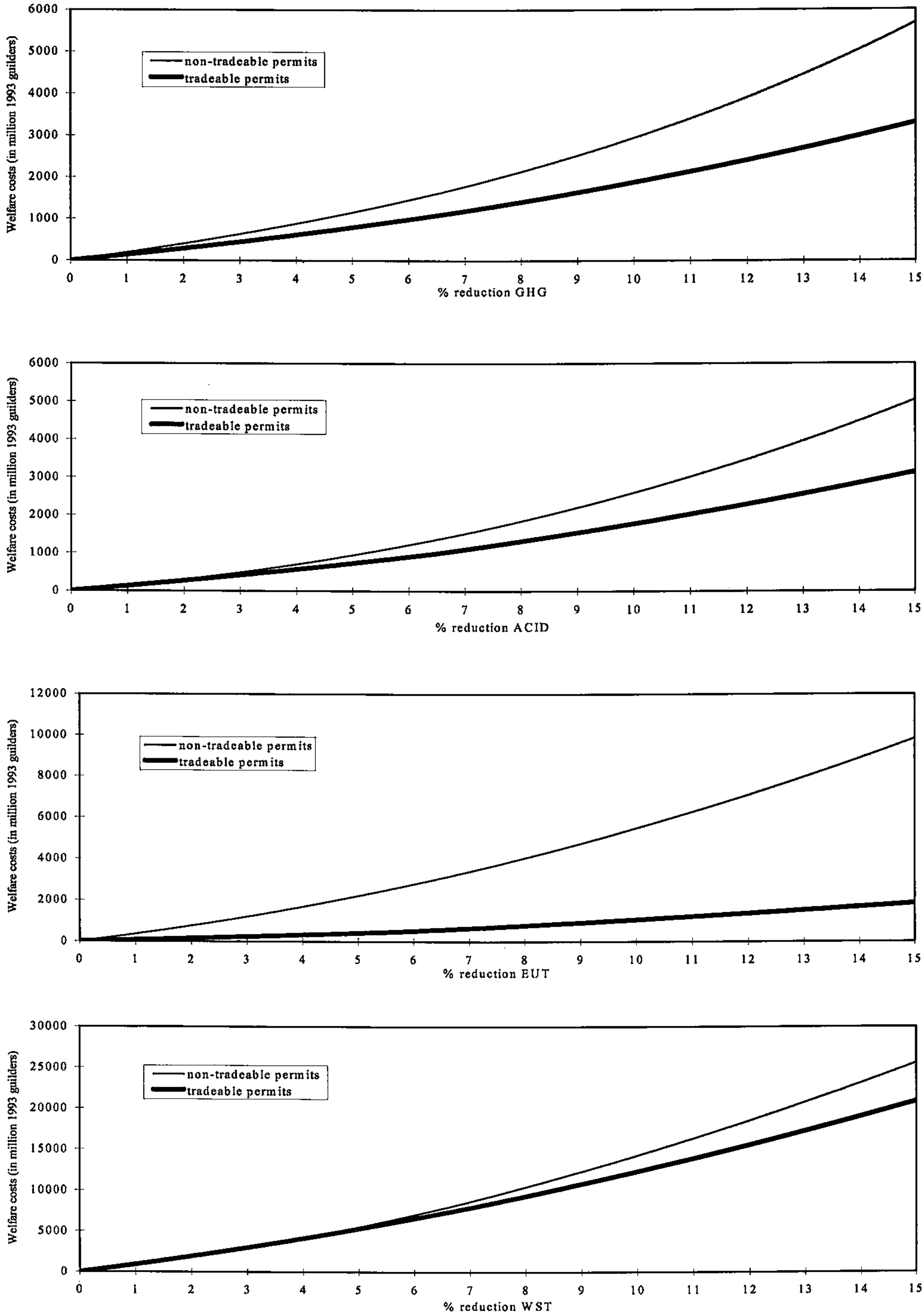


Figure XIII.1 *Welfare costs of reducing GHG, ACID, EUT and WST indicators*

Appendix XIV Technology description dairy farming

This appendix describes how the technologies in dairy farming, distinguished in Chapter 6, are defined. First the two technologies that are active in the benchmark are determined, using a cross-entropy procedure (Golan et al., 1996). Second, a latent clean technology is defined, using data from a Dutch experimental farm. All technologies are summarised in Table XIV.1 that also shows the use table for dairy farming (see Chapter 2), corrected for a milk quota rent of 1500 mln. (1993) guilders.[1]

Description active technologies

For dairy farming two active technologies are defined in the benchmark: a nitrogen (N) intensive technology (technology 1: dirty active) and a less N intensive technology (technology 2: clean active). The technologies are defined, using a stratified sample of specialised Dutch dairy farms that kept accounts on behalf of the Agricultural Economic Research Institute (LEI) farm accounting system (hereafter called LEI-sample). First, the average phosphate emissions per unit of milk output are determined for the whole LEI-sample[2]. The farms with more than the average phosphate emissions per unit of milk are denoted dirty; the farms with less than the average are denoted clean. The average farm of the dirty class has 10% more emissions per unit of milk than the average farm of the clean class.[3] The vector y of output by technologies in the AGE model is determined by the output share of the dirty and clean farms in the LEI-sample. To complete the production structure of the two technologies in the AGE model, also the input vector x has to be divided over the two technologies. The matrix Q of input shares for the two classes of farms, known from the LEI-sample can be used as prior information to determine a matrix P of input shares in the AGE model benchmark.

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1 The market value (lease price) of milk quota in 1993 is 0.34 guilders per kg (Boots, 1999, p. 83). The Dutch quota rent at market prices therefore would be 11.10^9 kg milk * 0,34 = 3750 million guilders which would absorb a large part of total value added in dairy farming. There are several reasons for the high market prices of milk quota among which are: market imperfections, strategic behaviour of farmers and tax deductibility of quota. Taking into account that investments in milk quota are tax deductible (highest marginal tariff is 60%), the quota rent is set, rather arbitrarily, equal to 1500 mln (1993) guilders.

2 Since N emissions are not presented in the LEI-sample, the distribution of P emissions is taken as a proxy for the distribution of N emissions, which is not a too crude assumption given the rather fixed relationship between these emissions.

3 This rather small difference is caused by the fact that the distribution of emission per unit of milk of the specialised dairy farms in the LEI-sample is condensed around the mean. If more than two classes had been distinguished, greater differences between classes would be expected. However, this would increase the number of active technologies and accordingly require more data.

Following Golan et al. (1996, p.59-64) the matrix P with I inputs for T technologies can be found, defining a cross-entropy problem that can be formalised as follows:

$$\underset{p_{t,i}}{Min} \sum_{t\in T}\sum_{i\in I} p_{t,i}.\ln p_{t,i} - \sum_{t\in T}\sum_{i\in I} p_{t,i}.\ln q_{t,i} \qquad \text{(XIV.1)}$$

Subject to:

$$\mathbf{y} = P.\mathbf{x} \qquad \text{(XIV.2)}$$

$$\sum_{t\in T} p_{t,i} = 1 \qquad \text{(XIV.3)}$$

where $p_{t,i}$ and $q_{t,i}$ are elements of the matrices P and Q.

Since the aggregation level of the inputs in the LEI-sample and the AGE model is not the same, only five inputs could be distinguished: labour (i=1), capital (i=2), cattle (i=3), compound feed (i=4) and other inputs (i=5).[4] From the LEI-sample the following prior matrix Q was obtained with five input shares for two technologies (clean and dirty):

$$Q = \begin{bmatrix} 0.462 & 0.460 & 0.483 & 0.454 & 0.394 \\ 0.538 & 0.540 & 0.517 & 0.546 & 0.606 \end{bmatrix}$$

Using $y = \begin{bmatrix} 4753 \\ 6414 \end{bmatrix}$ and $x = \begin{bmatrix} 193 \\ 3107 \\ 1192 \\ 2432 \\ 4243 \end{bmatrix}$, P can be found:

$$P = \begin{bmatrix} 0.451 & 0.449 & 0.472 & 0.443 & 0.384 \\ 0.549 & 0.551 & 0.528 & 0.557 & 0.616 \end{bmatrix}$$

Matrix P says that, for example, 45.1% of total labour (i=1) in dairy farming (193 million guilders) is used by technology 1 (87 million) and 54.9% is used by technology 2 (106 million). Hence, using P the input vector $\mathbf{x}$ can be divided in an input matrix X.

[4] In future research, more efforts should be made to match the level of aggregation in the LEI-sample and the AGE model to improve the description of distinguished technologies. Moreover, it should be taken into account that the LEI-sample represents specialised dairy farms (that partly produce other products than dairy) while the industries distinguished in the AGE model are fully specialised.

$$X = \begin{bmatrix} 87 & 1396 & 563 & 1077 & 1628 \\ 106 & 1711 & 629 & 1355 & 2615 \end{bmatrix}$$

This matrix is adjusted to the aggregation level of the AGE model presented in Table XIV.1, where the distribution of inputs G5, G6 and G12-G44 over the two technologies is identical to 'other inputs' (i=5) of matrix X (see Table XIV.1).

Table XIV.1 Input table technologies in dairy farming (values in million guilders at 1993 prices)

		Use table Dairy farming		Technology 1 Dirty active		Technology 2 Clean active		Technology 3 Clean new
	Input	Value	Share	Value	Share	Value	Share	Share
	Hired labour	193	0.017	87	0.018	106	0.017	0.019[a]
	Capital (incl. self employed)	3107	0.278	1396	0.294	1711	0.267	0.317[b]
	Economic loss	0	0.000	0	0.000	0	0.000	-0.003[c]
G1	Cattle	1192	0.107	563	0.118	629	0.098	0.118
G5	Grain	69	0.006	26	0.005	43	0.007	0.005
G6	Arable products n.e.c.	323	0.029	124	0.026	199	0.031	0.005[d]
G11	Compound feed	2432	0.218	1077	0.227	1355	0.211	0.224[e]
G12	Dairy products	4	0.000	2	0.000	2	0.000	0.000
G19	Food products n.e.c.	85	0.008	33	0.007	52	0.008	0.007
G21	Raw mat.leather/textiles/paper	36	0.003	14	0.003	22	0.003	0.003
G23	Building materials	43	0.004	17	0.004	26	0.004	0.004
G25	Other raw materials energy	18	0.002	7	0.001	11	0.002	0.001
G26	Fuels for vehicles	144	0.013	55	0.012	89	0.014	0.012
G27	Other fuels for heating	2	0.000	1	0.000	1	0.000	0.000
G29	Distributed gas	42	0.004	16	0.003	26	0.004	0.003
G30	Electricity	122	0.011	47	0.010	75	0.009	0.010
G31	Water	69	0.006	26	0.005	43	0.007	0.005
G32	Fertiliser	316	0.028	121	0.025	195	0.030	0.010[f]
G33	Other chemical products	54	0.005	21	0.004	33	0.005	0.004
G34	Pesticides	31	0.028	12	0.003	19	0.003	0.003
G36	Semi-manufact. metal products	12	0.001	5	0.001	7	0.001	0.001
G37	Metal products and machinery	16	0.001	6	0.001	10	0.002	0.001
G40	Garden and agr. services	980	0.088	376	0.079	604	0.094	0.096[g]
G41	Construction and ground work	247	0.022	95	0.020	152	0.024	0.020
G42	Transport services	2	0.000	1	0.000	1	0.000	0.000
G43	Cleaning services	18	0.002	7	0.001	11	0.002	0.001
G44	Other services	1610	0.144	618	0.130	992	0.155	0.130
	TOTAL	**11167**	**1.000**	**4753**	**1.000**	**6414**	**1.000**	**1.000**
	Milk quota rent	1500						
	TOTAL incl. quota rent	**12667**						
	N Emissions (million kg N)	354.58		159.56		195.02		
	N Emission /output	0.032		0.034		0.030		0.020[h]

[a] 2% more labour than technology 1
[b] 8% more capital than technology 1
[c] The input shares sum up to more than 100% of output since at benchmark prices there is an economic loss
[d] G6 in technology 1 consist of approximately 60% roughage, which is not bought under the new technology
[e] 1% less compound feed than technology 1
[f] 60% less fertiliser than technology 1
[g] 22% more agricultural services than technology 1
[h] 40% less N emissions than technology 1

Description latent technology

The inactive, latent technology (technology 3: clean new) is assumed to be an N extensive technology. Results of a comparison between normal and N extensive management of dairy farming at the 'Marke', a Dutch experimental farm, are used to describe the input vector of the third latent technology. Research at the 'Marke' showed that although the N extensive technology is feasible, due to more intensive use of non-N intensive inputs (labour, capital and agricultural services), it would run at an economic loss at benchmark prices in the AGE model (see: PR, 1998, table 9). The last column in table XIV.1 describes the new technology that represents the N extensive management at the 'Marke'. Assuming that technology 1 is equivalent to the normal management at the 'Marke', technology 3 is derived using the differences explained in the footnotes to the table.

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SUMMARY

There is a growing awareness of actual and potential threats to the natural environment in the form of the exhaustion of natural resources, the pollution of air, land and water resources, and the deterioration of bio-diversity. As in most industrialised countries, the concern for maintaining or improving environmental quality has taken a firm place on the policy agenda in the Netherlands. Hence, for policy makers and interest groups, it is important to understand the nature of different environmental problems, the linkages between the economy and the environment, and the economic and environmental consequences of government intervention.

The Dutch economy, agriculture and environment are highly interrelated. Agriculture, industries that are directly related to agriculture (agribusiness) and international trade in agricultural and food products form a substantial part of Dutch economic activity. Moreover, agricultural production causes a number of specific environmental problems, primarily related to the use of industrial inputs like fertiliser and pesticides. In addition, agriculture also contributes to some general environmental problems like the greenhouse effect, acidification and eutrophication.

Three relevant categories of policies can be distinguished that stress the changing policy environment of agriculture and the linkages that exist between the economy, the environment and agriculture: (1) environmental policies that are specific for agriculture; (2) general environmental policies that affect agriculture; and (3) agricultural policies that entail environmental effects. In addition, the importance of environmental policies relatively to other policies in agriculture is increasing. Hence, there is scope for empirical analysis of Dutch agriculture and agribusiness, in order to unravel the qualitative and quantitative relation between the environment and economic activity.

The purpose of this thesis is to quantify the economy-wide environmental and economic effects of agricultural and environmental policies and the interactions between these policies, in the Netherlands. Some of the most important policy issues are dealt with in this thesis. Policy simulations are: (1) the manure policy; (2) the introduction of a small-user energy tax; (3) the reduction of emissions contributing to the environmental indicators eutrophication, the greenhouse effect, acidification and waste accumulation; and (4) the increase of milk quota under a nitrogen emission restriction.

The basic tool used in this thesis is a static, single-country applied general equilibrium (AGE) model for the Dutch economy, in which environmental relations are incorporated explicitly. Given the linkages described and the economy-wide and trade effects that can be

expected from agricultural and environmental policies, using an AGE for a small open economy is appropriate. Moreover, the availability of new environmental data at a very disaggregated level for the Netherlands makes it possible, and from a scientific point of view interesting, to link environmental data to economic activity in an AGE model. Finally, an AGE model provides useful information on several variables that are relevant for policy makers and interest groups.

Chapter 2 presents and discusses the AGE model and data used. Since in the different policy simulations different modifications of the model are used, the description of the model is not exhaustive. Modifications of the model, used in the different policy simulations, are dealt with in the concerning chapters. A complete description of the basic model is presented in appendices. The chapter also deals with the economic and environmental data used. Data obtained from own calculations (e.g., detailed environmental data and disaggregation of agricultural data) are summarised in appendices.

In Chapter 3, the effects on the Dutch economy of a reduction in intensive livestock production are analysed. Such a reduction is a possible solution to environmental problems linked with the excess supply of minerals to the environment.

A decrease in intensive livestock production to achieve a phosphate loss of 30 kg/ha (policy goal in 2002) will decrease income from pig and poultry farming by 2.6 and 1.0 per cent, respectively. If pig production alone is reduced, the income from pig farming will decrease by 4.8 per cent. The lower production in pig and poultry farming affects the production and income of the compound feed, pig and poultry meat industries more seriously than the livestock industries because of the absence of quota rents as part of income. The effects on trade are that net exports of livestock and net imports of feedstuffs decrease. Moreover, in all cases, the exchange rate appreciates, which indicates that the trade position of the Netherlands would deteriorate because of the livestock reduction. In the case of a permitted phosphate loss of 30 kg/ha when only pig production is reduced, welfare decreases by 800 mln 1990 guilders which is only 0.15 per cent of national income. This welfare reduction would be offset by environmental improvements that are not included in the welfare measure.

The simulations give a good insight into the economic effects of a stricter mineral policy. It clearly shows that the introduction of an environmental policy that is specific for agriculture entails economy wide effects, revealing the linkages that exist between agriculture and the rest of the economy. The results form the background to discussions on the advantages and disadvantages of reducing Dutch livestock production and on the design of policies in other countries that deal with the same environmental problems. An important policy implication is the fact that industries related to the livestock industries (compound feed, pig and poultry meat industries) are affected more seriously than the livestock industries. This result is mainly due to the compensating effect of the quota rents for current farmers. However, the value of this quota (production rights) forms an entry barrier and has a negative effect on the structure of intensive livestock farming.

Chapter 4 deals with a general environmental policy that also has consequences for individual agricultural industries. In 1996, the Dutch government implemented an energy tax on fossil fuels for heating and electricity by households and 'small' energy users (small-user energy tax). The revenues of the energy tax are used to lower the pre-existing distortionary taxes related to labour. The research in this chapter shows the detailed environmental and economic effects of this Dutch unilateral environmental tax reform. Special attention is paid to the double-dividend argument that the introduction of a small environmental tax reform not only improves the environment (first dividend) but might also raise non-environmental welfare, due to an improvement in the efficiency of the tax structure (second dividend). The effects of the small-user energy tax are compared with a general energy tax, while also different tax recycling mechanisms are considered.

The simulations in this chapter show that the small-user energy tax (25 per cent for gas, 15 per cent for electricity, 25 per cent for coal and 20 per cent for other fuels for heating) causes a CO_2 reduction of 3.5 per cent while total emissions of greenhouse gases are reduced by 3.1 per cent. By recycling revenues of the small-user energy tax, employment increases by 0.10 per cent and existing tax distortions decrease, resulting in a higher national welfare of 0.06 per cent. The second best welfare improvement occurs due to the redistribution of existing tax distortions from labour to capital. When the tax base is broadened to all energy users and exemptions are ignored, welfare decreases by 0.02 per cent and the exchange rate increases by 0.25 per cent. This illustrates that in the case of a general energy tax, internati-onal competitiveness of the large energy-using industries deteriorates. Within agriculture, horticulture under glass is the most affected industry although the effects are small. Sensitivity analyses of the results show that the positive welfare effects of a small-user energy tax only apply at low tax rates. At higher tax rates, the negative distortionary effects of the introduction of a small-user energy tax dominate the positive effect of redistributing existing distortions from labour to capital. At a CO_2 reduction higher than 25 per cent, welfare costs of a small-user energy tax even become higher than welfare costs of a general energy tax, which is due to a broader tax base of the general tax.

The results show that it is rational to exempt large users from an energy tax to avoid loss of international competitiveness. Only at high reduction levels might it be more efficient to tax large energy users as well, since then an increased tax base proves to be less distorting. Under the restrictions of the model used, a second dividend can be achieved by the introduction of a small-user energy tax. At low tax rates, a welfare improvement is even possible when the revenues of a small-user energy tax are recycled in a lump sum fashion. These typical second-best results occur due to an inefficient initial distribution of the tax burden. From a policy perspective the question remains, however, whether introducing an energy tax is the appropriate tool to reduce distortions caused by other taxes.

The Dutch government has developed environmental policy targets, specified in terms of environmental indicators that measure phenomena like the greenhouse effect, acidification, eutrophication, and waste accumulation. Typically, each policy target entails a reduction in emissions that cause the environmental problem measured by the indicator. Chapter 5 analyses the environmental and economic effects of restricting these indicators, using a system of emission permits for the Netherlands. Indicators are linked to inputs, aggregate output, consumer goods and aggregate consumption at a very detailed level. Agriculture is an important contributor to these environmental indicators. The analysis focuses on the different effects of restricting single environmental indicators, the effects of restricting different environmental indicators simultaneously and the tradeability of emission permits.

The results in this chapter show large differences in welfare losses as result of restricting different environmental indicators, which can be explained by the extent to which inputs, aggregate output, consumer goods and aggregate consumption can be substituted. In the case of waste emissions and to a lesser extent of eutrophication, where emissions are related to aggregate output and aggregate consumption, substitution is hardly possible and a reduction of emissions will therefore be very costly. In the case of acidification and greenhouse gas emissions, however, a reduction can be achieved by substitution of zero or low emission commodities for high emission commodities, which entails relatively low costs. Moreover, in the latter case, emissions are widely distributed over all industries and consumers, which, especially in the case of tradeable emission permits, offers scope for an efficient allocation of the emission reduction. These results emphasise the need for a very detailed emission matrix at a disaggregated level as applied in this chapter. The simulations also show that environmental policies might interact, when different environmental indicators are related to the same economic variables. When two or more environmental policy goals are set simultaneously, individual restrictions are less restrictive and hence shadow prices of restrictions will be lower. In addition, the welfare loss of an additional environmental restriction is relatively small. Finally, the simulations in this chapter show the potential benefits of a system of tradeable permits over a system of non-tradeable permits. When permits are tradeable, permit prices for 1 kg CO_2 equivalent (greenhouse effect), 1 mole H^+ (acidification), 1 kg N equivalent (eutrophication) and 1 kg waste (waste accumulation) at 10 per cent reduction of the concerning emissions are 0.04, 0.18, 1.52 and 3.37 guilders (1993) respectively. These are lower than the average shadow prices in the case of non-tradeability (0.13, 1.03, 21.43 and 9.41 respectively). The difference in welfare loss between non-tradeable and tradeable permits is largest in the case of eutrophication (5476 vs. 1060 million guilders) which is due to the large differences in eutrophication emission coefficients between agents.

From a policy perspective, the simulations in this chapter give insight into the potential effects of achieving different environmental policy goals. Since both direct and indirect effects are taken into account in the AGE framework used, the links between environmental problems and economic activity are placed in a broad perspective. The simulation results show that the economic impact of an emission reduction depends largely on substitution possibilities. Since these possibilities are often limited, especially when emissions are related to output, there is a potential pay-off to increasing the search for low-emission technologies. Moreover, confirming the results obtained in earlier studies, the gain of a tradeable emission permit system over a non-tradeable system shows the need for a market-based approach when emissions have to be reduced. Finally, since restrictions on different environmental indicators might interact, there is clearly scope for policy co-ordination when multiple environmental policy goals are to be met.

Chapter 6 focuses on the environmental and economic effects of an agricultural policy change. It analyses the effects of an increase in milk quota in the Netherlands when nitrogen (N) emissions in agriculture are restricted. This policy simulation is an example of an agricultural policy change that entails environmental effects. In addition, it clearly shows the linkages between agricultural industries. The AGE model applied in this chapter is written in mixed-complementarity format (AGE-MC model), in which dairy farming is represented by a series of different Leontief technologies. Each technology is characterised by a different emission-input-output mix. Consequently, technology switches make it feasible to reduce emissions without necessarily reducing output, which would be the case if emissions were related to output in a well-behaved neoclassical production technology.

The results show that as milk quota rights become less scarce, the value of milk quota reaches zero. Since N emissions in agriculture are restricted, a higher production in dairy farming will lead to a positive and increasing shadow price of N emissions. At the point where milk quota is no longer restrictive, the shadow price is 0.99 guilders (1993) per kg N. A welfare gain can be reached by increasing milk quota while keeping N emissions at the same level. Under such a policy change, inactive N-extensive technologies in dairy farming become active and (partly) replace N-intensive technologies, while output in other agricultural industries decreases. The latter shows that policy measures taken in one industry may indirectly (through the market for N emissions) entail effects in other industries.

The simulations in Chapter 6 show that results are sensitive to the specification of technology in dairy farming. The AGE-MC approach, using multiple Leontief technologies, seems to be more flexible than using the single CES technology. If the AGE-MC approach is adopted, results depend on the specification of the alternative (both existing and latent) technologies. Especially latent technologies are difficult to specify because of a lack of information. However, if this information is available the AGE-MC approach is a useful tool for policy analysis in cases where technology switches can be expected as a result of policy changes.

The policy simulations in this thesis clearly reveal the economy-wide environmental and economic effects of agricultural and environmental policies and the interactions between these policies, in the Netherlands. However, the results should be interpreted with care for several reasons. First, since real policies are usually too complicated to be tackled in an economic model, there is always the chance of a certain degree of policy mis-specification. For example, the presence of energy covenants (in horticulture) or seasonal manure application norms are difficult to deal with in an AGE model. Second, it is worth mentioning that policies could be subject to large changes during the period in which applied policy research can be completed. Policies that first look premature, may eventually be implemented and finally turn out to be replaced or supplemented by other policies. Finally, the results are conditional on the model and data characteristics; for example, functional forms, specification of agents and commodities, and the static nature of the model. Therefore, for some of the critical assumptions (factor mobility, trade, and labour supply) sensitivity analyses were performed.

Considering the remarks and conclusions in the preceding chapters, several suggestions for future research are coming to the fore. First, in order to get more insight into the interaction between agricultural and environmental policies, there are still some policy simulations left to deal with, like a simulation on pesticides policy and policy simulations related to the CAP reform. Second, since a drawback of the AGE model is that it is not econometrically estimated, maximum entropy econometrics (an estimation techniques for small samples) in combination with frequently published SAMs could be used in the future to (partially) estimate AGE models. Third, an interesting area of research might be to incorporate micro-econometric simulation models into AGE models. Many issues in environmental economics require both detailed insights at the level of the decision-making units (e.g., individual farms) and the consequences of such decisions for the environment and the economy as a whole. Micro-econometric simulation models, on the one hand, provide detailed insight at the level of the farm (sometimes sector) and incorporate technological differences between farms. AGE models, on the other hand, consider the linkages with the rest of the economy but are less detailed. Theoretically, a link is possible given that both types of model are based on micro-economic theory. Finally, it may be interesting in further research to consider regional differences in agriculture, using regional Social Accounting Matrices (SAMs). The appearance and functioning of rural areas is receiving increasing attention because of issues like rural employment, nature production and countryside maintenance and conservation. Since agriculture contributes to rural activity and largely determines the appearance of the countryside, regional differentiation is appropriate.

SAMENVATTING (Summary in Dutch)

Er is een groeiend bewustzijn van actuele en potentiële bedreigingen van het milieu in de vorm van uitputting van natuurlijke hulpbronnen, de vervuiling van lucht, grond en water, en verslechtering van de biodiversiteit. Zoals in de meeste geïndustrialiseerde landen, heeft de zorg voor het in stand houden en verbeteren van de milieukwaliteit een vaste plaats ingenomen op de beleidsagenda in Nederland. Dientengevolge is het voor zowel beleidsmakers als belangengroepen van belang om de achtergrond van de verschillende milieuproblemen, de verbanden tussen economie en milieu, en de gevolgen van overheidsingrijpen voor economie en milieu te kunnen doorgronden.

De Nederlandse economie, landbouw en het milieu hangen in hoge mate met elkaar samen. De landbouw, industrieën rechtstreeks verbonden met de landbouw (agribusiness) en internationale handel in landbouw- en voedselproducten vormen een substantieel deel van de Nederlandse economische activiteiten. Daarnaast veroorzaakt de landbouw een aantal specifieke milieuproblemen, voornamelijk gerelateerd aan het gebruik van industriële inputs als kunstmest en pesticiden. Bovendien draagt de landbouw bij aan een aantal algemene milieuproblemen, zoals het broeikaseffect, verzuring en eutrofiëring.

Drie belangrijke categorieën beleid kunnen worden onderscheiden die de veranderende beleidsomgeving en de verbanden die bestaan tussen economie, milieu en landbouw, benadrukken: (1) Milieubeleid die specifiek is voor de landbouw; (2) algemeen milieubeleid die invloed heeft op de landbouw; en (3) landbouwbeleid die milieueffecten veroorzaakt. Bovendien neemt de importantie van milieubeleid relatief tot ander beleid in de landbouw toe. Derhalve is empirische analyse van de landbouw en agribusiness van belang om de kwalitatieve en kwantitatieve relatie tussen milieu en economische activiteit bloot te leggen.

Het doel van dit proefschrift is om de economische- en milieueffecten van landbouw- en milieubeleid, en de interactie daartussen, voor de gehele Nederlandse economie te kwantificeren. Een aantal van de belangrijkste beleidsissues worden behandeld in dit proefschrift. Beleidssimulaties zijn: (1) het mestbeleid; (2) de introductie van een kleinverbruikerheffing op energie; (3) de reductie van emissies die bijdragen aan de milieu-indicatoren eutrofiëring, het broeikaseffect, verzuring en afvalophoping; en (4) het vergroten van melkquota onder een restrictie op stikstofemissies in de landbouw.

Het basisinstrument dat gebruikt is in dit proefschrift betreft een toegepast algemeen evenwichtsmodel (Applied General Equilibrium model; AGE model) voor de Nederlandse economie, waarin milieurelaties expliciet zijn opgenomen. Gegeven de hierboven beschreven verbanden en de effecten voor de gehele economie en internationale handel die verwacht kunnen worden van landbouw- en milieubeleid, is het gebruik van een AGE model voor een kleine open economie geschikt. Bovendien maakt de beschikbaarheid van nieuwe milieudata voor Nederland op een zeer gedesaggregeerd niveau het mogelijk en wetenschappelijk interessant om binnen een AGE model milieudata te koppelen aan economische activiteiten. Tenslotte verschaft een AGE model bruikbare informatie over verschillende variabelen die van belang zijn voor beleidsmakers en belangengroepen.

Hoofdstuk 2 presenteert en bediscussieert de basisversie van het AGE model en de gebruikte data. Omdat in de verschillende beleidssimulaties verschillende varianten van het model worden gebruikt, is de beschrijving van het model niet uitputtend. Varianten van het model die voor de verschillende beleidssimulaties worden gebruikt, worden in de betreffende hoofdstukken behandeld. Een complete beschrijving van het basismodel vindt plaats in appendices. Het hoofdstuk behandelt ook de gebruikte economische- en milieudata. Data die zijn verkregen door eigen berekeningen (bijvoorbeeld gedetailleerde milieudata en de desaggregatie van landbouwdata) zijn samengevat in appendices.

In hoofdstuk 3 worden de effecten van een reductie van de intensieve veehouderij voor de Nederlandse economie geanalyseerd. Zo'n reductie is een mogelijke oplossing voor milieuproblemen die gerelateerd zijn aan het overschot van mineralenaanvoer naar het milieu.

Een inkrimping van de intensieve veehouderij om een fosfaatverlies van 30 kg/ha te bereiken (beleidsdoel in 2002) zal het inkomen van de varkens- en pluimveehouderij doen afnemen met respectievelijk 2.6 en 1.0 procent. Als alleen de varkensproductie wordt ingekrompen, neemt het inkomen in de varkenshouderij af met 4.8 procent. De lagere productie in de varkens- en pluimveehouderij heeft grotere gevolgen voor de productie en het inkomen in de veevoederindustrie en de vleesverwerkende industrie dan voor de intensieve veehouderij zelf, omdat de waarde van de productie quota, die deel uitmaakt van het inkomen in de intensieve veehouderij, ontbreekt. De effecten voor de internationale handel zijn dat de netto exporten van vee en netto importen van veevoer afnemen. Bovendien apprecieert de wisselkoers in alle simulaties hetgeen aangeeft dat de handelspositie van Nederland verslechtert ten gevolge van de inkrimping van de veestapel. In het geval van een fosfaatverlies van 30 kg/ha, waarbij alleen de varkenshouderij wordt ingekrompen, neemt de welvaart af met 800 miljoen gulden (1990) hetgeen slechts 0.15 procent van het nationaal inkomen is. Deze welvaartsafname zou moeten worden gecompenseerd door een milieuverbetering die echter geen deel uitmaakt van de gebruikte welvaartsmaatstaf.

De simulaties geven een goed inzicht in de gevolgen van een strikter mineralenbeleid. Er wordt duidelijk weergegeven dat de introductie van milieubeleid die specifiek is voor de landbouw gevolgen heeft voor de gehele economie, wat de verbanden tussen de landbouw en de rest van de economie aantoont. De resultaten vormen de achtergrond voor discussies over de voor- en nadelen van het inkrimpen van de Nederlandse veestapel en voor het ontwerpen van beleid in andere landen, die te maken hebben met dezelfde milieuproblemen. Een belangrijke beleidsimplicatie vormt het feit dat de gevolgen voor industrieën die gerelateerd zijn aan de intensieve veehouderij (veevoederindustrie en de vleesverwerkende industrie) groter zijn dan voor de intensieve veehouderij zelf. Dit resultaat is met name het gevolg van het compenserende effect van de waarde van de productiequota voor de huidige veehouders. Echter, de waarde van de productiequota (productierechten) vormt tevens een toetredingsbarrière hetgeen een negatief effect heeft op de structuur van de intensieve veehouderij.

Hoofdstuk 4 handelt over een algemeen milieubeleid die ook consequenties heeft voor individuele landbouwsectoren. In 1996 heeft de Nederlandse overheid een energieheffing ingevoerd op het gebruik van elektriciteit en fossiele brandstoffen t.b.v. verwarming door huishoudens en andere kleine verbruikers (kleinverbruikerheffing op energie). De revenuen van de energieheffing worden gebruikt om de reeds bestaande verstorende belastingen op arbeid te verlagen (terugsluizen). Het onderzoek in dit hoofdstuk geeft de gedetailleerde milieu- en economische effecten weer van deze Nederlandse unilaterale hervorming van belasting op milieu. Speciale aandacht wordt besteed aan het argument van het 'dubbel dividend' dat de introductie van zo'n belastinghervorming niet alleen het milieu verbetert (eerste dividend) maar ook de welvaart verhoogt in economische zin (tweede dividend) ten gevolge van een verbetering van de efficiëntie van de belastingstructuur. De effecten van een kleinverbruikerheffing worden vergeleken met een algemene energieheffing terwijl tevens alternatieve terugsluizingsmechanismen worden beschouwd.

De simulaties in dit hoofdstuk tonen aan dat de kleinverbruikerheffing (25 procent voor gas, 15 procent voor elektriciteit, 25 procent voor steenkool en 20 procent voor andere brandstoffen voor verwarming) een CO_2 reductie teweegbrengt van 3.5 procent terwijl de totale emissies van broeikasgassen verminderen met 3.1 procent. Door de revenuen van de kleinverbruikerheffing terug te sluizen, neemt de werkgelegenheid toe met 0.1 procent en bestaande belastingverstoringen nemen af, hetgeen resulteert in een hogere nationale welvaart van 0.06 procent. Deze *second best* welvaartsverbetering ontstaat door de herverdeling van bestaande belastingverstoringen van arbeid naar kapitaal. Indien de grondslag van de belastingen wordt verbreed naar alle energieverbruikers en vrijstellingen genegeerd worden (algemene energieheffing), neemt de welvaart af met 0.02 procent en de wisselkoers stijgt met 0.25 procent. Dit illustreert dat in het geval van een algemene energieheffing, de internationale concurrentiepositie van de grote energieverbruikende industrieën verslechtert. Alhoewel de effecten klein zijn, zijn de gevolgen binnen de landbouw voor de glastuinbouw het grootst. Gevoeligheidsanalyses tonen aan dat de positieve welvaartseffecten van een kleinverbruikerheffing alleen van toepassing zijn bij lage belastingtarieven. Bij hogere belastingtarieven domineren de negatieve verstorende effecten van de introductie van de energieheffing de positieve effecten van het herverdelen van de belastingverstoring van arbeid naar kapitaal. Bij een CO_2 reductie die hoger is dan 25 procent zijn de welvaartskosten van een kleinverbruikerheffing zelfs groter dan die van een algemene energieheffing hetgeen wordt veroorzaakt door de bredere belastinggrondslag van de algemene energieheffing.

De resultaten tonen aan dat het rationeel is om grote energieverbruikers vrij te stellen van een energieheffing om een verlies aan internationale concurrentiekracht te voorkomen. Alleen bij hoge reductieniveaus zou het efficiënter kunnen zijn om ook grote energieverbruikers te belasten, omdat dan de grotere belastinggrondslag minder verstorend blijkt te zijn. Onder de condities van het gebruikte model kan een tweede dividend worden bereikt ten gevolge van de introductie van een kleinverbruikerheffing. Bij lage belastingtarieven is zelfs een welvaartsverbetering mogelijk door de revenuen van de kleinverbruikerheffing lumpsum terug te sluizen. Deze typische *second best* resultaten treden op door een inefficiënte initiële verdeling van de belastingverstoring. Vanuit beleidsperspectief blijft echter de vraag of het introduceren van een energieheffing een adequaat instrument is om verstoringen, die door andere belastingen worden veroorzaakt, te verlagen.

De Nederlandse overheid heeft milieubeleidsdoelen ontwikkeld, uitgedrukt in milieu-indicatoren die verschijnselen meten als het broeikaseffect, verzuring, eutrofiëring en afvalophoping. Kenmerkend is dat elk beleidsdoel een reductie teweegbrengt van emissies die het milieuprobleem veroorzaakt die wordt gemeten met de betreffende milieu-indicator. Hoofdstuk 5 analyseert de milieu- en economische effecten van het beperken van deze indicatoren, gebruikmakend van een systeem van emissierechten voor Nederland. Indicatoren zijn gerelateerd aan inputs, geaggregeerde output, consumptiegoederen en geaggregeerde consumptie, op een zeer gedetailleerd niveau. De landbouw levert een belangrijke bijdrage aan deze milieu-indicatoren. De analyse concentreert zich op de verschillende effecten van het beperken van elke milieu-indicator apart, de effecten van het beperken van verschillende milieu-indicatoren gelijktijdig en de verhandelbaarheid van emissierechten.

De resultaten in dit hoofdstuk laten grote verschillen in welvaartsverliezen zien als gevolg van het beperken van de verschillende milieu-indicatoren hetgeen kan worden verklaard door de mate waarin inputs, geaggregeerde output, consumptiegoederen en geaggregeerde consumptie kunnen substitueren. In het geval van afvalemissies en in mindere mate van eutrofiëring, waar emissies gerelateerd zijn aan geaggregeerde output en geaggregeerde consumptie, is substitutie nauwelijks mogelijk en zal een reductie van emissies derhalve zeer kostbaar zijn. In het geval van verzuring en broeikasgasemissies kan een reductie echter wel plaatsvinden door substitutie van goederen met hoge emissies door goederen met lage of geen emissies, hetgeen relatief lage kosten teweegbrengt. Bovendien zijn in het laatste geval de emissies ook veel breder verspreid over alle industrieën en consumenten, hetgeen, met name in het geval van verhandelbare emissierechten, ruimte biedt voor een efficiënte allocatie van de emissiereductie. Deze resultaten benadrukken de noodzaak van een zeer gedetailleerde emissiematrix op een gedesaggregeerd niveau, zoals toegepast in dit hoofdstuk. De simulaties laten ook zien dat verschillende milieubeleidsdoelen interactie kunnen vertonen indien verschillende milieu-indicatoren gerelateerd zijn aan dezelfde economische variabelen. Wanneer twee of meer milieubeleidsdoelen tegelijkertijd worden nagestreefd, zijn de individuele restricties minder beperkend en zal dientengevolge de schaduwprijs van de restricties lager zijn. Bovendien is het welvaartsverlies van een additioneel milieubeleidsdoel relatief klein. Tenslotte laten de simulaties in dit hoofdstuk zien wat de potentiële voordelen van een systeem van verhandelbare emissierechten zijn ten opzichte van een systeem van niet verhandelbare emissierechten. Bij verhandelbare emissierechten zijn de prijzen voor de rechten van 1 kg CO_2 equivalent (broeikaseffect), 1 mol H^+ (verzuring), 1 kg N equivalent (eutrofiëring) en 1 kg afval (afvalophoping) bij een 10 procent reductie van de betreffende emissies, respectievelijk 0.04, 0.18, 1.52 en 3.37 gulden (1993). Deze prijzen zijn lager dan de gemiddelde schaduwprijzen indien emissierechten niet verhandelbaar zijn (respectievelijk 0.13, 1.03, 21.43 en 9.41 gulden). Het verschil in welvaartsverlies tussen een systeem van verhandelbare en niet verhandelbare emissierechten is het grootst voor eutrofiëring (1060 vs. 5476 mln gulden), wat het gevolg is van de grote verschillen in emissiecoëfficiënten tussen de verschillende economische agenten.

Vanuit beleidsperspectief geven de simulaties in dit hoofdstuk inzicht in de potentiële effecten van het bereiken van verschillende milieubeleidsdoelen. Omdat zowel directe als indirecte effecten in ogenschouw worden genomen in het gebruikte AGE framework, worden de verbanden tussen milieuproblemen en economische activiteit in een breder perspectief geplaatst. De simulaties laten zien dat de economische impact van een emissiereductie in hoge mate afhangt van de substitutiemogelijkheden. Omdat deze mogelijkheden vaak beperkt zijn, met name wanneer emissies gerelateerd zijn aan output, kan er een potentieel voordeel behaald worden door te zoeken naar lage-emissie-technologieën. Het voordeel van een systeem van verhandelbare emissierechten ten opzichte van een systeem van niet verhandelbare emissierechten toont aan dat een marktgerichte benadering vereist is indien emissies gereduceerd moeten worden. Dit bevestigt de resultaten die ook in andere studies worden verkregen. Tenslotte, omdat restricties op verschillende milieu-indicatoren interactie vertonen, is beleidscoördinatie in het geval van meerdere beleidsdoelstellingen van grote betekenis.

Hoofdstuk 6 concentreert zich op de milieu- en economische effecten van een verandering in landbouwbeleid. Het analyseert de effecten van een verruiming van melkquota in Nederland terwijl stikstofemissies (N) in de landbouw beperkt worden. Deze beleidssimulatie is een voorbeeld van een verandering van landbouwbeleid die milieueffecten teweegbrengt. Bovendien worden de verbanden tussen de landbouwsectoren duidelijk aangetoond. Het AGE model dat toegepast is in dit hoofdstuk, is geschreven in *mixed-complementarity format* (AGE-MC model), waarin de melkveehouderij wordt gerepresenteerd door een reeks Leontief technologieën. Elke technologie wordt gekarakteriseerd door een verschillende emissie-input-output mix. Dientengevolge maken technologiewisselingen het mogelijk emissies te reduceren zonder dat noodzakelijkerwijs output wordt gereduceerd, hetgeen het geval zou zijn geweest indien emissies worden gerelateerd aan output onder een *well-behaved* neoklassieke productietechnologie.

De resultaten laten zien dat de waarde van melkquota daalt indien melkquota worden verruimd. Omdat N emissies in de landbouw beperkt zijn, leidt een hogere productie in de melkveehouderij tot een positieve en toenemende schaduwprijs van N emissies. Op het punt waar melkquota niet langer restrictief zijn, bedraagt de schaduwprijs 0.99 gulden (1993) per kg N. Een welvaartswinst kan worden bereikt door het uitbreiden van melkquota terwijl N emissies op hetzelfde niveau worden gehouden. Ten gevolge van de beleidsverandering worden inactieve N-extensieve technologieën in de melkveehouderij actief en vervangen zij (gedeeltelijk) N-intensieve technologieën, terwijl de productie in andere landbouwsectoren afneemt. Dit laatste toont aan dat beleidsmaatregelen die worden genomen in de ene sector indirect (via de markt voor N emissierechten) effecten teweegbrengen in andere sectoren binnen de landbouw.

De simulaties in hoofdstuk 6 tonen aan dat de resultaten gevoelig zijn voor de specificatie van de technologie in de melkveehouderij. De AGE-MC benadering, die gebruik maakt van meerdere Leontief technologieën, lijkt flexibeler dan het gebruik van een enkele CES technologie. Als de AGE-MC benadering gebruikt wordt, hangen de resultaten af van de specificatie van alternatieve (zowel bestaande als latente) technologieën. Vooral latente technologieën zijn moeilijk te specificeren wegens een gebrek aan informatie. Als deze informatie echter beschikbaar is, vormt de AGE-MC benadering een bruikbaar instrument voor beleidsanalyses in gevallen waarin technologiewisselingen verwacht kunnen worden ten gevolge van beleidsveranderingen.

De beleidssimulaties in dit proefschrift tonen duidelijk de milieu- en economische effecten aan van landbouw- en milieubeleid en de interacties daartussen, voor de Nederlandse economie. Echter, de resultaten moeten met zorg worden geïnterpreteerd voor verschillende redenen. Ten eerste, omdat het echte beleid vaak te gecompliceerd is om te simuleren met een economisch model, bestaat er altijd een bepaalde mate van foute specificatie van het beleid. Bijvoorbeeld, het bestaan van energie convenanten (in de tuinbouw) of de seizoensgebonden voorschriften voor het verspreiden van mest zijn moeilijk te vertalen naar een AGE model. Ten tweede dient opgemerkt te worden dat beleid vele malen kan veranderen in de tijd waarin toegepast onderzoek kan worden afgerond. Beleidsmaatregelen die in eerste instantie voorbarig lijken, worden later toch ingevoerd om tenslotte weer vervangen of aangevuld te worden door andere maatregelen. Tenslotte zijn de resultaten afhankelijk van het model en de data karakteristieken; bijvoorbeeld de functievormen, de specificatie van de economische agenten en goederen, en de statische eigenschappen van het model. Daarom zijn in dit proefschrift voor enkele kritische aannames (factor mobiliteit, handel en arbeidsaanbod) gevoeligheidsanalyses uitgevoerd.

Met het oog op de opmerkingen en conclusies uit voorgaande hoofdstukken, komen enkele suggesties voor toekomstig onderzoek naar de voorgrond. Ten eerste, om meer inzicht te krijgen in de interactie tussen landbouw- en milieubeleid is er nog een aantal beleidssimulaties mogelijk zoals een simulatie van het pesticidenbeleid of simulaties van de hervorming van het gemeenschappelijk landbouwbeleid in de Europese Unie. Ten tweede, omdat een belangrijk nadeel van het AGE model is dat het niet econometrisch geschat is, kan in de toekomst *maximum entropy* econometrie (een schattingstechniek voor kleine steekproeven) worden gebruikt om AGE modellen (gedeeltelijk) te schatten. Ten derde vormt een interessant onderzoeksterrein wellicht het incorporeren van micro-econometrische simulatiemodellen in AGE modellen. Veel aspecten in de milieu-economie vereisen zowel een gedetailleerd inzicht op het niveau van de beslissende economische agent (bijvoorbeeld op boerderij niveau) als de consequenties van zulke beslissingen voor het milieu en de economie als geheel. Micro-econometrische simulatie modellen verschaffen een gedetailleerd inzicht op boerderijniveau (soms sectorniveau) en bevatten technologische verschillen tussen bedrijven. AGE modellen beschouwen met name de verbanden met de rest van de economie, maar zijn minder gedetailleerd. Theoretisch is een koppeling mogelijk, gegeven het feit dat beide typen modellen gebaseerd zijn op micro-economische theorie. Tenslotte is het in verder onderzoek wellicht interessant de regionale verschillen in de landbouw te beschouwen, gebruikmakend van regionale rekeningen. Het aanzicht en functioneren van rurale gebieden krijgt in toenemende mate aandacht door issues als rurale werkgelegenheid, natuurproductie en instandhouding van het platteland. Omdat de landbouw bijdraagt aan de rurale activiteit en in grote mate het aanzicht bepaalt van het platteland, is regionale differentiatie gewenst.

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CURRICULUM VITAE

Marinus Hendrikus Cornelis Komen werd geboren op 23 december 1968 te Den Helder. Van 1981 tot 1987 doorliep hij het Voorbereidend Wetenschappelijk Onderwijs (V.W.O) op de Rijksscholensgemeenschap in Schagen. Vervolgens studeerde hij van 1987 tot 1992 aan de Agrarische Pedagogische Hogeschool STOAS in Dronten, waar hij de 5-jarige leraren-opleiding Agrarische Economie voltooide.

In 1992 begon hij het doorstroom-programma Agrarische Economie aan de toenmalige Landbouwuniversiteit Wageningen. In 1995 studeerde hij cum laude af met als afstudeer-vakken Algemene Economie en Algemene Agrarische Economie. Voor het eerstgenoemde afstudeervak verbleef hij gedurende 3 maanden aan de University of Wyoming. Voor het laatstgenoemde afstudeervak ontving hij in 1995 de C.T. de Wit scriptieprijs.

In april 1995 begon hij als Onderzoeker In Opleiding aan een promotieonderzoek bij de toenmalige vakgroep Algemene Agrarische Economie en Landbouwpolitiek, Landbouw-universiteit Wageningen. Dit onderzoek werd gefinancierd door de Nederlandse Organisatie voor Wetenschappelijk Onderzoek en de Stichting voor de Economische Sociaal-culturele en Ruimtelijke Wetenschappen (NWO-ESR). In 1997 behaalde hij het diploma van het landelijk Netwerk Algemene en Kwantitatieve Economie (NAKE).

Sinds april 1999 is hij als universitair docent verbonden aan de vakgroep Agrarische Economie en Plattelandsbeleid, Wageningen Universiteit. Zijn huidige onderzoek betreft o.a. de analyse van de samenhang tussen milieu, landbouw en agribusiness en de economische analyse van milieu- en landbouwbeleid. Onderzoeksresultaten zijn gepubliceerd in diverse internationale wetenschappelijke tijdschriften en gepresenteerd tijdens diverse internationale wetenschappelijke congressen.