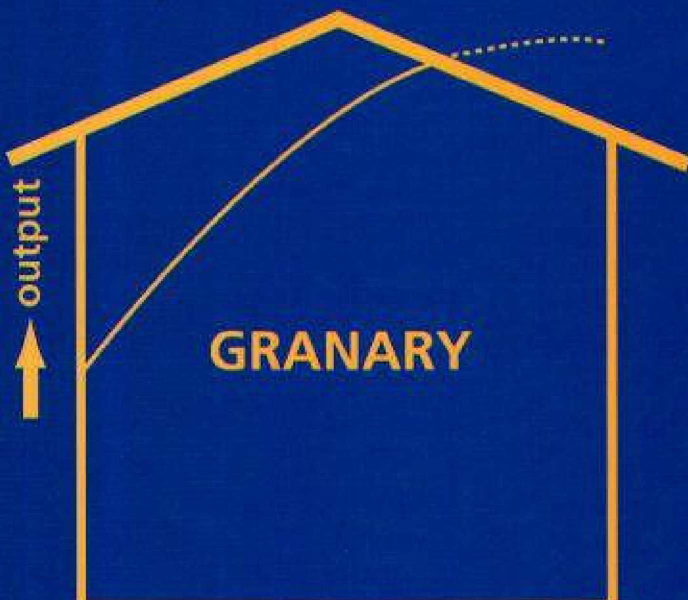
Micro-economic models for analysing policy changes in Dutch arable farming



Alfons Oude Lansink

Stellingen

1) Wanneer paneldata beschikbaar zijn, bieden Maximum Entropy schattingsmethoden de mogelijkheid om preciezere voorspellingen te doen over de effecten van beleidsveranderingen dan Fixed-Effect schattingsmethoden (*Golan, A., G. Judge and D. Miller (1996). Maximum Entropy Econometrics : Robust Estimation with Limited Data, Chichester*)

2) Het begrip zuinigheid behoeft opwaardering in het kader van de noodzaak om zuinig om te gaan met uitputbare hulpbronnen.

3) Wetenschappers moeten zich er bij uitstek van bewust zijn dat op 'human capital' moet worden afgeschreven.

4) Studies die beogen technische efficiency verschillen tussen bedrijven te meten, meten vaker het effect van het weglaten van inputs die belangrijk zijn in het productieproces dan echte technische efficiency verschillen.

5) Het gebruik van een Fixed Effects schattingsmethode resulteert in kleinere prijselasticiteiten dan schattingsmethoden die zowel van variatie tussen groepen als variatie binnen groepen gebruikmaken. *(dit proefschrift)*

6) In economisch mindere tijden prefereren Nederlandse akkerbouwers afschrijven boven actief desinvesteren als middel om de hoeveelheid machines te optimaliseren *(dit proefschrift)*.

7) Het omvangrijke systeem van fiscale aftrekposten ondermijnt in sterke mate de progressiviteit van het Nederlandse belastingstelsel.

8) Trouwen danwel samenwonen verhoogt de transactiekosten van het beëindigen van een relatie en vergroot zodoende de stabiliteit ervan (*Dixit, A. and R. Pindyck (1994). Investment under uncertainty, New Jersey*).

9) De "warme deken" van de kleine dorpsgemeenschap kan zowel comfortabel als verstikkend zijn.

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Preface

The thesis that lies in front of you is the product of four years of research that I performed as a PhD. student (A.I.O.) at the department of Agricultural Economics and Policy of Wageningen Agricultural University. I started the work back in September, 1992 after I graduated as a master student in Agricultural Economics, at the same university. Part of the research was also performed at the department of Agricultural Economics and Rural Sociology of the Pennsylvania State University, where I spent four months in the summer of 1995.

Several chapters of the thesis have been written together with other researchers and/or have been published in journals and series. Chapter 2 was written together with Geert Thijssen and was published as Oude Lansink and Thijssen (1994), whereas Chapter 3 was published as Oude Lansink (1995). Chapters 4 and 5 have been written together with Jack Peerlings and were published as Oude Lansink and Peerlings (1996) and Oude Lansink and Peerlings (1997). Chapter 7, finally is co-authored with Spiro Stefanou from Pennsylvania State University.

I am very much indebted to my supervisors Arie Oskam and Geert Thijssen, for their valuable comments on earlier drafts and for allowing me freedom in selecting research topics and methods. They have also been very helpful to me in developing a critical attitude and learning professional skills.

I also wish to thank the colleagues from the department of agricultural Economics and Policy and all who visited the department, for creating a pleasant and professional environment. Especially I want to mention Wilbert Houweling for his technical assistance, Alison Burrell for her valuable comments on all chapters of the thesis and Jack Peerlings and Spiro Stefanou, with whom I have collaborated intensively during the research of this thesis and whom I owe insights and motivation through numerous discussions. I am also grateful to all fellows of the Network for Quantitative Economics, who provided courses, that increased my understanding and theoretical knowledge of economics.

Special thanks also go the Agricultural Economics Research Institute (LEI-DLO) in the Hague for its willingness to provide the data that have been used intensively in this thesis.

And last but not least, I want to thank Ingeborg for her dedicated support throughout the years that I worked on my thesis and, when necessary, for being very helpful in diverting my thoughts away from economics.

Wageningen, August 1996

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Chapter 1

Introduction

1.1 Background and scope

Environmental and agricultural policy measures are sources of an increasing number of restrictions on agricultural production. Examples of environmental policy that will influence Dutch arable farming are the long-term crop protection plan (LCPP) and mineral policy. The LCPP aims among other things to lower the average 1984-'88 level of pesticide use. The arable sector uses about two thirds of all pesticides used in the Netherlands. Targeted reductions for this sector are 39% in 1995 and 60% in 2000 (MJP-G, 1991 : 101). Mineral policy aims at reducing the flow of phosphates and nitrogen to the environment. Policy with respect to the arable sector will probably take the form of a mandatory registration of mineral flows on the farm. The surplus that is calculated using this information will serve as a tax base (Tweede Kamer, 1995). Future environmental policy with respect to the arable farming sector may also involve variables as CO_2 emission, water use and nature/landscape production, but this thesis will not deal with these issues.

Other policy changes that affect arable farming stem from the Common Agricultural Policy (CAP). In 1992, the EU reduced price support for cereals and abolished the deficiency payments for oilseeds and protein crops. To compensate farmers for their income loss, subsidies per hectare were introduced. However, farmers growing more than 92 tonnes of cereals equivalents have to set aside a predetermined share of their area of cereals, oilseeds and protein crops (LNV, 1992). Also, as a result of the CAP-reform, prices of cereals will be less stable than before.

The (proposed) policy changes often have detailed implications at the farm level and require therefore explicit modelling in order to determine their effects on economic (e.g. income, input and output levels) and environmental variables (e.g. mineral surplus).

Farms in the Dutch arable sector are mainly small scale farms operated by the farmer and his family. This implies that arable farmers are price takers in the markets of inputs and outputs and that neoclassical production theory and especially its dual form (e.g. profit function) is a convenient framework for describing economic behaviour of arable farmers. Advantages of the dual form over the primal form include conceptual and computational convenience and simplicity and the possibility of using a broader range of functional forms[1] (Shumway, 1995).

Developments in the literature on applied duality theory can be characterised along three broad lines :

- Application of static duality theory : Following Lau and Yotopoulos (1972) many authors (e.g. Binswanger 1974; Sidhu and Baanante, 1981; Shumway, 1983; Weaver, 1983; Wall and Fisher, 1986) have applied duality theory to agricultural economic issues (see also Shumway, 1995).
- Application of dynamic duality theory : Theoretical contributions of McLaren and Cooper (1980) and Epstein (1981) were soon followed by applications to agriculture (e.g. Taylor and Monson, 1985; Vasavada and Chambers, 1986; Howard and Shumway, 1988).
- Duality under uncertainty : Several authors have now established duality results in the static framework under price uncertainty Coyle, 1992; Saha and Just, 1996; Paris, 1989) and output uncertainty (Chavas and Pope, 1994; Pope and Just, 1996; Coyle, 1995). Duality under price uncertainty in a dynamic framework has recently been addressed by Arnade and Coyle (1995).

The application of static duality theory under price certainty is well developed in the literature, so the first purpose of this thesis is to determine the effects of the aforementioned policy changes using static dual micro economic models. The contribution of this thesis is that it explicitly incorporates the technical details of the policy changes. A further contribution lies in the use of farm level data. Previous authors have used farm

[1] Because no system of first order conditions has to be solved to derive input demand and/or output supply equations (Shumway, 1995).

level data for estimation and testing[2] (Elhorst, 1991; Thijssen, 1992a) and provided model results for an 'average' farm. This thesis extends their analyses by using farm level data for simulating policy changes and calculating the effects for different classes of farms and the sector.

Applications of duality under uncertainty in both the static and dynamic framework are still very scarce in the literature, so the second purpose of the thesis is to make a contribution in this area by providing an application of static duality theory under price uncertainty.

Applications of dynamic duality theory have frequently used aggregate data. The use of farm level data brings about additional problems related to the occurrence of zero investments in fixed factors. Therefore, the third purpose of this thesis is to develop a methodology for modelling individual farmers' investment behaviour in a dynamic dual framework.

This thesis starts however with a more general chapter that contributes to the literature by developing a general framework for testing functional specifications of the profit function. The purpose of this chapter is to provide a rigorous criterion for selecting functional forms in the remaining chapters of the thesis.

1.2 Outline of the thesis

In this section, a short discussion of the background and main contents of chapters 2-7 is provided.

The performance of flexible functional forms : Testing against the Box-Cox

The specification of the functional form for the profit function can be viewed as a random model specification, i.e. it is an approximation to the 'true' function. The literature on functional form selection however frequently relies on ad hoc criteria such as

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[2] It is important to note that many applied studies use aggregate data (e.g. sector level), although the theory that is used, holds at the level of the individual firm. Testing micro economic theory while using aggregate data is not necessarily valid, since there is no reason to assume a priori that the theory holds for an aggregate of firms, even if it holds for each firm separately (Shumway, 1995).

theoretical consistency, domain of applicability, flexibility, computational ease, plausibility of the estimated elasticities and others (Lau, 1986; Baffes and Vasavada, 1989).

Chapter 2 presents a unifying approach to allowing the data reveal the specification by employing the Generalised Box-Cox framework and using Double Length artificial Regression. Three different linear functional form specifications of the profit function (Normalised Quadratic, Symmetric Normalised Quadratic and Generalised Leontief) are tested on the data set that is used for the analyses in the following chapters. An extended version of the Generalised Box-Cox is developed which includes these three specifications as nested hypotheses. A Lagrange Multiplier test that avoids estimation is used to test (subsets of) functional forms against (simplifications of) the linear GBC. Functional forms are also evaluated in terms of regularity conditions, parameter significance and reasonability of elasticities. The Normalised Quadratic outperforms the other forms on most criteria and is used in most chapters in the thesis.

Effects of input quotas in Dutch arable farming

Taxes, subsidies and quantitative restrictions are among the most commonly used instruments in environmental policy (Baumol and Oates, 1988). When introducing combined tax/quota policies, one should take into account that price elasticities are affected by the introduction of the quota (Guyomard and Mahé, 1993). In particular, the own price elasticities are smaller in absolute terms, when an input or output is restricted : the Le Chatelier-Samuelson effect.

Chapter 3 considers the effects for an average arable farm of a hypothetical introduction of a pesticides quota. The methodology that is used in this chapter is already known from consumption theory, but has recently been extended to production theory (Fulginiti and Perrin (1993), Guyomard and Mahé (1993) and Squires (1993)). In particular, attention is paid to the effects on price elasticities, elasticities of intensity and shadow prices of fixed inputs and the restricted quantity of pesticides after the quota introduction. Furthermore, the possibilities of the methodology are demonstrated by calculating the effects on netput quantities and income of a combination of input quotas and taxes.

Modelling EU cereals and oilseeds regime in the Netherlands

Following the new regime for cereals and oilseeds in the EU, area and set-aside premiums are coupled to the area of cereals, oilseeds and pulses. The quantity of land set aside depends on the farmer's area of these crops. In previous research either one or both of these aspects have not been accounted for. Guyomard et al. (1993) analysed the new CO regime assuming that area premiums are either fully coupled or fully decoupled from price levels. Moreover, set-aside decisions were exogenous in their model. Jensen and Lind (1993) accounted for the fact that area and set-aside premiums are decoupled from price support, but they did not allow set-aside decisions to be endogenous in their model. The contribution of Chapter 4 to the existing literature analysing the new CO regime is that both these aspects are accounted for. This is possible because the effects are examined at the level of the individual farm. The decision to participate in the set-aside programme is endogenous in our model and depends among other things on prices of inputs and outputs and the level of the area and set-aside premiums. Regional aspects of the new regulation are also taken into account as are environmental effects concerning the use of pesticides and N-fertiliser.

The reactions of arable farms in the Netherlands are examined using a simulation model consisting of equations that are estimated using panel data for Dutch arable farms. The results of the estimation are used in a simulation model that calculates the short-term effects of the new CO regime for the farms that are in the panel. Simulation results are aggregated for different classes of farms and for the sector as a whole.

Effects of N-surplus taxes : Combining technical and historical information

Future policies on minerals will probably oblige all farms to keep a mineral account for flows of nitrogen and phosphates from manure as well as artificial fertiliser (Tweede Kamer, 1995). In this way detailed information on uptake of minerals by crop products and supply of minerals through artificial fertiliser and manure will be available. The difference between supply and uptake, minus a threshold level for acceptable mineral losses per hectare, constitutes mineral surpluses per farm which will be taxed.

In Chapter 5 the effects of a tax on Nitrogen surplus are determined. To this end, a general methodology is developed that allows technical information on the production of an externality to be included in a dual profit function to yield insight into the effects of a tax on the externality. This methodology is used to extend the model that was developed in the previous chapter with nitrogen surplus equations. The model that is thus obtained is capable of determining the effects of agricultural policy measures and mineral policy measures simultaneously.

Area allocation under price uncertainty : A dual approach

Although empirical evidence has shown that income uncertainty is an important determinant in area allocation (Freund, 1958; Collender and Zilberman, 1985; Babcock et al.,1987; Chavas and Holt, 1990), so far a dual framework has not been developed for simultaneous area allocation and production/input decisions under income risk. Advantages of the dual versus the primal framework have been discussed extensively in the literature (Pope, 1982; Shumway, 1995). They include computational convenience, simplicity, estimation efficiency and the possibility to use a broader range of functional forms.

Chapter 6 uses a Mean-Standard deviation utility function to build a dual model that simultaneously determines area allocation and production/input decisions under price uncertainty. The specification of the Mean-Standard deviation utility function is sufficiently flexible to characterise various risk configurations. Moreover, regularity conditions of the underlying indirect utility function (symmetry, convexity) and the producers risk preferences are tested.

Asymmetric adjustment of dynamic factors at the firm level

While in the short term, some inputs or outputs may be assumed fixed, in the long term this assumption does not hold. A dynamic specification of a profit function enables modelling decisions on quasi-fixed inputs explicitly.

In the standard approach to modelling quasi-fixed factor demand, zero investments are optimal if the shadow value of the quasi-fixed factor is zero. The observation from firm level data where investments are frequently zero questions the consistency of the standard approach to modelling firm level decision making. A theoretical problem thus arising is that the first order condition for optimization of the value function, which is implicit in the dual approach, is not necessarily satisfied. An econometric problem arising in both the primal and dual approach is that the data are censored in the presence of zero investments. This implies that the standard assumption of independent and identically distributed errors no longer applies and results in biased estimates, if not corrected.

Chapter 7 addresses these shortcomings of past approaches through the specification and estimation of a threshold model to characterise investment demand. The threshold model maintains investments are zero if the shadow value of capital is between a lower and an upper threshold. This model is estimated in two stages. The first stage determines the decision whether to invest, disinvest or do nothing. This information is used to correct the error terms in the second stage which comprises the estimation of a system of output supply and variable and quasi-fixed factor demand equations. Since the value function does not necessarily exist for zero investments, only the observations for which investments are non-zero are used in the second stage.

1.3 Data

The models in this thesis are estimated on data on specialised arable farms, covering the period 1970-1992[3]. These data were obtained from a stratified sample of Dutch farms which kept accounts on behalf of the LEI-DLO farm accounting system. Specialised arable farms are defined as farms with more than 80% of output coming from marketable crops. Farms stay in the panel for only five to six years, so the panel is incomplete.

The models include outputs, variable inputs and quasi-fixed inputs. Outputs primarily comprise sugar beet, ware potatoes, seed potatoes and starch potatoes, winter-wheat, barley, oats, oilseeds, and animal output. Variable inputs are mainly pesticides, fertilisers, services, non-nitrogenous fertiliser, seed and planting materials, purchased feed input, energy.

Quasi-fixed inputs are land, labour and capital. Land is measured in hectares. Labour is measured in quality-corrected man years, and includes family as well as hired labour. Hired labour accounts for a small portion (17%) of total labour at the farm level

[3] In chapters 2 and 3, the data set covered the period 1970-1988. Data over the period 1989-1992 were not available at the time these chapters were written.

and is included as a fixed input since labour contracts cannot easily be terminated. Capital includes capital invested in machinery and livestock, and is measured at constant 1980 prices. Capital invested in buildings was not included since it proved impossible to obtain a reliable value of buildings for all farms in the sample (Elhorst, 1990: p.84).

Table 1 gives an overview of the mean and standard deviation of variables that are included in the empirical models[4]. Quantities of outputs, variable inputs, land and capital increased in the period 1970-1992 whereas labour remained almost constant. A more general description of characteristics of Dutch arable farming and developments in farm structure etc in the past two decades can be found in LEI-DLO (1995a).

In the empirical models of chapters 2-7, variable inputs and outputs are aggregated to categories of implicit input and output quantity indices. Implicit quantity indices are obtained as the ratio of value to price index. Prices of individual components of aggregates are obtained from LEI-DLO, whereas prices of input and output aggregates are defined as Törnqvist price indices and are well documented in e.g. Higgins (1986) and Thijssen (1992a). The implication of using Törnqvist price indices is that the underlying aggregator function is translog (Diewert, 1976). Price indexes vary over the years but not over the farms, implying that differences in the composition of a netput or quality differences are reflected in the quantity (Cox and Wohlgenant, 1986; Thijssen, 1992a).

Output prices are not known at the time decisions are made on planting and the use of variable inputs, so expected rather than actual prices have to be used. Expected output prices were constructed, assuming that price expectations are formed according to an autoregressive (AR) proces. The implication of using expected rather than actual prices is that expected profit is assumed to be maximised instead of actual profit. Expected profit is defined as expected revenue (expected prices times quantities of outputs) minus the total value of the variable inputs actually used.

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4 Input and output categories are not the same in all models of this thesis. A more detailed description of the data can be found in chapters 2-7.

Table 1 : Mean values of variables for arable farms in the period 1970-1992 (standard deviations in parentheses).

year	output[a]	variable inputs[a]	land[b]	labour[c]	capital[a]
1970	173.0	89.2	40.0	19.7	136.7
	(96.6)	(1.5)	(4.3)	(10.1)	(87.0)
1971	213.3	93.2	42.5	18.6	146.1
	(146.3)	(63.0)	(30.6)	(10.6)	(94.2)
1972	184.9	87.4	42.4	16.8	147.6
	(111.8)	(51.4)	(26.1)	(7.5)	(92.9)
1973	200.8	91.7	45.2	17.1	162.8
	(115.1)	(54.9)	(26.0)	(8.1)	(94.3)
1974	200.4	91.2	44.7	16.7	165.7
	(119.9)	(54.2)	(27.7)	(8.1)	(103.1)
1975	199.7	91.3	47.1	17.3	186.3
	(120.6)	(53.3)	(32.0)	(8.7)	(118.8)
1976	220.9	100.0	47.5	17.3	196.0
	(148.7)	(60.6)	(32.3)	(9.4)	(128.8)
1977	274.3	114.7	47.5	17.2	215.0
	(217.5)	(73.7)	(31.9)	(9.3)	(145.5)
1978	276.3	114.1	49.6	17.6	244.9
	(186.2)	(72.3)	(34.9)	(9.3)	(165.3)
1979	281.2	114.4	50.9	17.4	262.1
	(193.7)	(77.6)	(35.9)	(9.2)	(176.9)
1980	272.3	112.0	52.0	16.9	275.4
	(181.3)	(72.1)	(39.1)	(9.3)	(178.4)
1981	273.9	111.2	52.4	17.0	286.8
	(188.4)	(87.6)	(39.3)	(9.5)	(186.7)
1982	325.7	112.3	53.3	16.1	284.3
	(207.6)	(70.5)	(39.3)	(8.3)	(177.6)
1983	263.1	117.3	53.2	16.5	293.1
	(166.2)	(74.7)	(39.2)	(8.1)	(181.6)
1984	367.4	134.0	55.9	17.1	317.8
	(248.3)	(81.0)	(37.5)	(9.2)	(193.1)
1985	376.2	136.3	57.3	17.3	329.7
	(260.9)	(80.6)	(37.3)	(9.5)	(211.3)
1986	415.8	139.5	59.3	17.1	333.3
	(294.8)	(92.5)	(44.0)	(9.8)	(227.5)
1987	408.0	135.6	59.3	16.6	333.4
	(293.0)	(84.0)	(40.4)	(8.6)	(232.5)
1988	386.5	129.4	59.4	16.3	338.4
	(269.3)	(80.2)	(40.1)	(8.3)	(236.9)
1989	408.7	135.1	61.3	16.6	339.1
	(259.4)	(82.2)	(40.7)	(8.6)	(246.3)
1990	444.6	139.6	61.7	16.7	341.9
	(290.4)	(84.9)	(40.3)	(8.6)	(242.6)
1991	438.6	139.1	60.7	16.4	344.8
	(290.5)	(83.1)	(39.0)	(8.3)	(235.7)
1992	589.4	131.9	63.1	16.8	359.7
	(430.3)	(76.4)	(37.9)	(8.3)	(236.0)

a) 1000 guilders of 1980
b) hectares
c) man years x 10

Chapter 2

Testing among Functional Forms : An Extension of the Generalised Box-Cox Formulation

Summary

This chapter uses the Generalised Box-Cox framework and Double Length artificial Regression to test whether different specifications of the profit function are able to mimic the technology underlying panel data of Dutch arable farms for the period 1970-1988. To this end, a linear GBC is developed that includes the Generalised Leontief, Normalised Quadratic and Symmetric Normalised Quadratic as special cases. A Lagrange multiplier test that avoids estimation of the linear GBC is used to test (subsets of) functional forms against (simplifications of) the linear GBC. Functional form results are also evaluated in terms of regularity conditions, parameter significance and reasonability of elasticities.
On this data set, the NQ outperforms the other forms on most criteria.

2.1 Introduction

The behavioural and technological characterisation of decision making has important implications for policy analysis. The question is how to let the data reveal such characterisations without imposing the limiting restrictions of functional specification and the estimation procedures to develop point estimates. Empirical work (e.g. Baffes and Vasavada, 1989) has demonstrated that parameter estimates and elasticities are sensitive to the functional form chosen. Hence the functional specification of a profit or cost function can be viewed as a random model specification; i.e. is profit adequately represented by a Normalised Quadratic, Generalised Leontief specification or something else?.

The Cobb-Douglas and the CES function were very popular before duality theory became widely employed. These forms are simple, their parameters are easy to interpret in economic terms, and they are usually not rejected by empirical evidence. However, they impose constraints on production relationships. Since the early 1970s a number of flexible functional forms (FFFs) has been introduced, the most commonly used being the Translog introduced by Christensen, Jorgenson and Lau (1973), the Generalised Leontief (GL) introduced by Diewert (1971), and the Normalised Quadratic (NQ) introduced by Lau (1978). In 1987 Diewert and Wales introduced the Symmetric Generalised MacFadden, which was extended by Kohli (1993) to the Symmetric Normalised Quadratic (SNQ).

Selecting functional forms has been one way the choice of the functional form has been addressed in the literature. This literature frequently relies on ad hoc selection criteria such as theoretical consistency, domain of applicability, flexibility, computational ease, factual conformity, satisfying curvature restrictions, plausibility of the estimated elasticities and others (Lau, 1986; Baffes and Vasavada, 1989). Baffes and Vasavada, (1989) could not select a functional form, because different functional forms yielded inconsistent results for the same data set.

Few researchers have tried to test whether a particular functional form outperforms all others. One approach uses Monte Carlo experiments to generate data from a known technology and examines the ability of the various forms to track this technology (e.g. Guilkey et al. 1983). Since the data generating process is known, this approach is appropriate if interest is centred on the general performance of a functional form; conclusions drawn from it do not necessarily carry over to other data sets. Yet another approach uses real data and estimates the Generalised Box-Cox (GBC), which is considered to be the 'true' function underlying the unknown data generating process. The GBC includes a variety of functional forms as nested hypotheses and parametric tests are carried out to test these against the GBC (Applebaum, 1979; Chalfant, 1984). Unfortunately the Box-Cox function has the disadvantage of rendering the model highly nonlinear in parameters and only few researchers have succeeded in actually estimating the Box-Cox.

This chapter presents an approach to allowing the data to reveal the character of technology by employing the Generalised Box-Cox framework and using double length artificial regressions (DLR) to employ a rigorous criteria towards identifying an appropriate specification of the profit function. The Box Cox model is extended to allow for the NQ and SNQ as special cases. The advantage of DLR is that it avoids cumbersome estimation of the Box-Cox in order to test nested forms against it (Davidson and MacKinnon (1984, 1993)). This chapter shows that DLR is also useful in testing against simplifications of the GBC, which are created by imposing restrictions on the GBC's transformation parameters. In this respect a test for linear homogeneity of the functions is developed. The model is estimated using panel data of Dutch arable farms over the period 1970-1988. The availability of panel data was explicitly taken into account in the sense that farm-specific effects are added to the equations.

This study focuses on the performance of the class of linear functional forms, thereby excluding the Translog. Although the Translog imposes fewer restrictions a priori on the technology than linear functional forms do (Lopez, 1985), it has some serious drawbacks that restrict its applicability. First, the log transformation of profit restricts the domain of applicability to positive profits. Negative profits may frequently occur when using a profit function that includes one or more restricted outputs (see Moschini, 1988; Helming et al., 1993). Second, the Translog is not capable of dealing with zero profit shares of inputs or outputs that may occur when using panel data. Third, the Translog does not allow for imposing curvature conditions globally, without destroying its flexibility (Diewert and Wales, 1987). The characteristic of testing and/or imposing curvature conditions globally is desirable when estimation results are used for e.g. policy simulations. Fourth, in dynamic models or models including risk behaviour the Translog form is not very useful because it results in functions that are difficult or impossible to estimate (Coyle, 1992).

The remainder of this chapter is organised as follows. In Section 2.2, the linear Box-Cox model is developed and the three linear functional forms distinguished are derived. An explanation of the DLR approach and a description of the steps involved are given in Section 2.3. The data and the estimation method are described in Section 2.4 and the empirical results are presented in Section 2.5. In addition to the tests performed with DLR against the Box-Cox, the functional forms are evaluated in terms of conditions following from duality theory, parameter significance and reasonability of the elasticities. This chapter concludes with comments on this research.

2.2 Three Functional Forms as Special Cases of the linear Box-Cox

Previous studies (e.g. Applebaum (1979), Berndt and Khaled (1979) and Shumway (1989)) have shown that the family of quadratic forms and the Generalised Leontief can be obtained as special or limiting cases of the Generalised Box-Cox (GBC). To date, the Normalised Quadratic and the Symmetric Normalised Quadratic have not been accounted for explicitly in the framework of the GBC. To be able to incorporate them, there must be a more general representation of the GBC, which we propose to call the linear Generalised Box-Cox :

$$\begin{aligned}\pi(\tau) = u + \sum_{i=1}^{3} \alpha_i v_i(\lambda,\tau) + \frac{1}{2}(\sum_{k=1}^{3} \theta_k v_k)^{\tau-1} \sum_{i=1}^{3} \sum_{j=1}^{3} \alpha_{ij} v_i(\lambda,\tau)\, v_j(\lambda,\tau) + \tau^2 \sum_{j=1}^{3} \beta_j c_j(\lambda) \\ + \frac{1}{2}(\sum_{k=1}^{3} \theta_k v_k)^{1-\tau} \sum_{i=1}^{3} \sum_{j=1}^{3} \beta_{ij} c_i(\lambda)\; c_j(\lambda) + \sum_{i=1}^{3} \sum_{j=1}^{3} \gamma_{ij} v_i(\lambda,\tau)\; c_j(\lambda)\end{aligned} \tag{2.1}$$

where

$$\pi(\tau) = \pi / v_3^{\tau} \tag{2.2}$$

$$v_i(\lambda,\tau) = \left(v_i / v_3^{\tau}\right)^{\lambda} \qquad for\ i=1,2 \tag{2.3}$$

$$v_3(\lambda,\tau) = (1-\tau)\left((v_3 / v_3^{\tau})^{\lambda'} - \tau\right) \tag{2.4}$$

and

$$c_i(\lambda) = c_i^{\lambda} \tag{2.5}$$

represent a simplified Box-Cox transformation (Box and Cox, 1964) of respectively profit (π), netput prices (v) and fixed inputs (c)[1]. The Box-Cox transformation used in this chapter is simplified because, unlike previous studies (Applebaum, 1979; Berndt and

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[1] Profit is defined as revenue minus variable costs; in this study three netputs and three fixed inputs are distinguished, but any other number of netputs and fixed inputs could have been chosen.

Khaled, 1979), log-linear forms (e.g. Translog) are not included in this study.

The τ and λ parameters are the parameters which are used to obtain the three functional forms, whereas u, α, β, and γ are the parameters of the profit function. The θ_i parameters are non-negative constants used in the SNQ, which may be selected by the researcher[2]; all other parameters can be estimated. In our GBC specification, we largely followed the notation used by other authors, as far as λ is concerned. However, we included the parameter τ to allow linear homogeneity to be imposed either through normalisation by v_3 in case of the NQ and GL or by the term $\Sigma_{k=1}^{3}\theta_i v_i$ in case of the SNQ. It can be seen that the term $\Sigma_{k=1}^{3}\theta_i v_i$ appears in the nested forms when τ is zero; at the same time, all $\beta_j c_j$ terms drop out when the Box-Cox transformation is written out. These are necessary conditions for the SNQ in order to satisfy linear homogeneity in prices. The quadratic expression of τ is required before that of $\beta_j c_j$, because otherwise the β_j parameters, which are not estimated in the SNQ model will be necessary to construct the DLR (section 2.3). The numeraire price v_3 is operational when τ is one, whereas the terms $(1-\tau)$ and $-\tau$ in the Box-Cox transformation of v_3 ensure that all terms $v_3(\lambda,\tau)$ disappear at the same time. As a result, the coefficients related to v_3 are not necessary to construct the DLR of the GL and NQ (see section 2.3).

Before discussing the three functional forms that we analyse in greater detail, we will introduce some notation that will be useful in the rest of this chapter : $v_i^* = v_i/v_3^\tau$ and $\pi^* = \pi/v_3^\tau$. The three functional forms can be obtained as limiting or special cases of the GBC by varying the parameters λ and τ (see Table 2.1).

Table 2.1 : Functional forms nested in the linear Generalised Box-Cox

λ	τ	Implied functional form
0.5	1	Generalised Leontief
1	1	Normalised Quadratic
1	0	Symmetric Normalised Quadratic

[2] In this study, the Θ_i are the average share of netput i in total cost plus revenue. They can be interpreted as fixed weights for the price index $\Sigma\Theta_i v_i$ (Kohli, 1993).

The GL is given by :

$$\pi^* = u + \sum_{i=1}^{2} \alpha_i (v_i^*)^{0.5} + \sum_{j=1}^{3} \beta_j c_j^{0.5} + \sum_{i=1}^{2}\sum_{j=1}^{2} \alpha_{ij} (v_i^* v_j^*)^{0.5} + \sum_{i=1}^{3}\sum_{j=1}^{3} \beta_{ij} (c_i c_j)^{0.5} + \sum_{i=1}^{2}\sum_{j=1}^{3} \gamma_{ij} (v_i^* c_j)^{0.5} \quad (2.6)$$

where all prices and profit are normalised by the price of other variable inputs in order to impose linear homogeneity in prices. Imposing symmetry requires $\alpha_{ij}=\alpha_{ji}$ and $\beta_{ij}=\beta_{ji}$ for all i and j. These symmetry restrictions apply to all functional forms distinguished.
The NQ takes the form :

$$\pi^* = u + \sum_{i=1}^{2} \alpha_i \, v_i^* + \sum_{j=1}^{3} \beta_j c_j + \frac{1}{2}\sum_{i=1}^{2}\sum_{j=1}^{2} \alpha_{ij} v_i^* v_j^* + \frac{1}{2}\sum_{i=1}^{3}\sum_{j=1}^{5} \beta_{ij} c_i c_j + \sum_{i=1}^{2}\sum_{j=1}^{3} \gamma_{ij} v_i^* c_j \quad (2.7)$$

whereas the SNQ is derived as :

$$\pi = u + \sum_{i=1}^{3} \alpha_i v_i + \frac{1}{2}\left(\sum_{k=1}^{3} \theta_k v_k\right)^{-1} \sum_{i=1}^{3}\sum_{j=1}^{3} \alpha_{ij} v_i v_j + \frac{1}{2}\left(\sum_{k=1}^{3} \theta_k v_k\right) \sum_{i=1}^{3}\sum_{j=1}^{3} \beta_{ij} c_i c_j + \sum_{i=1}^{3}\sum_{j=1}^{3} \gamma_{ij} v_i c_j \quad (2.8)$$

For the SNQ function u should be equal to zero because the linear homogeneity restriction allows no constant term in this function. In order to identify all parameters, additional restrictions have to be imposed on the SNQ:

$$\left(\sum_{j=1}^{3} \alpha_{ij} \bar{v}_j\right) = 0 \qquad \forall i \neq j$$

where $\bar{v}_j$ is an arbitrary point or observation. In this study $\bar{v}_j$ equals the sample mean.

It is important to note that the linear GBC is not linear homogeneous in prices and that linear homogeneity is imposed in the functional forms that are distinguished. Therefore, the test of the NQ, SNQ and GL against the linear GBC is not only a test of the specific transformation that is applied but also a test of linear homogeneity in prices.

Apart from testing against the linear GBC, it is also possible to simplify the linear Generalised Box-Cox, by imposing restrictions on the parameters of the linear GBC a priori. The restriction that we analyse is linear homogeneity of the GL, NQ and SNQ by testing on τ while maintaining $\lambda=0.5$ and $\lambda=1$, respectively.

2.3 Testing Against Generalised Box-Cox

Assuming that the linear GBC is the true model, we want to test whether one of the FFFs in the previous section is an acceptable simplification. The simplest way would be to estimate the linear Box-Cox and perform parametric tests on the three nested models. The linear generalised Box-Cox model, equation (2.1), is highly non-linear in parameters and is therefore difficult to estimate. Therefore if the only objective is to test the adequacy of simplifications of the Generalised Box-Cox, it is better to avoid such estimation (Davidson and MacKinnon, 1985). A possible solution would be to perform a grid search over values of the linear Box-Cox parameters (λ and τ) and estimate the parameters α, β, and γ conditional on the Box-Cox parameters. Another approach is to rescale the dependent variable. However, neither of these methods generates valid estimates of the covariance matrix of the parameters (Davidson and MacKinnon, 1993; 486-488).

Another strategy would be to calculate the values of the log-likelihood functions for various values of the linear Box-Cox parameters and to use an LR test to select among them. One disadvantage of this approach is that more than one model may turn out to be plausible. A second disadvantage is that the approach cannot tell us anything about the validity of the preferred model. The model might even be rejected if we actually tested it against the linear Box-Cox model (Davidson and MacKinnon, 1993; 489-492).

Several tests have been developed in the literature for the special case of testing the linear against the log-linear model. Godfrey et al. (1988) give an overview and provide some Monte Carlo evidence on the finite sample behaviour of several tests. The test based on Double Length artificial Regression (DLR - see Davidson and MacKinnon, 1984) is generally the most powerful one when the disturbances are normally distributed. Consequently, this test proves to be sensitive to failures of the normality assumption.

To understand the test based on DLR, let us develop the likelihood function of equation (2.1). We add an additive disturbance term to this equation to take account of measurement errors in the dependent variable, optimisation errors and effects of a large number of omitted variables. The disturbance terms are assumed to be normally distributed with mean zero and variances σ^2. We rewrite equation (2.1) by subtracting the regressors from the regressand and dividing the resulting term on the left-hand side by σ. The resulting equation can be written as

$$m_n (y_n, \omega) = e_n \qquad n = 1.....N \tag{2.9}$$

where each m_n is a function of observation n which depends on the dependent variable y_n, the exogenous variables, vector of parameters ω; e_n has a standard normal distribution; and N is the number of observations. The parameter ω contains α, β, γ, λ, τ and σ. The density of e_n is equal to:

$$f_1(e_n) = \frac{1}{\sqrt{2\pi}} \exp\left(-\tfrac{1}{2} e_n^2\right) \tag{2.10}$$

In order to construct the likelihood function, we need the density of y_n rather than the density of e_n. The density of y_n is given by:

$$\begin{aligned} f_2(y_n) &= f_1\left(m_n(y_n,\omega)\right) \left| \frac{\partial m_n(y_n,\omega)}{\partial y_n} \right| \\ &= \frac{1}{\sqrt{2\pi}} \exp\left(-\tfrac{1}{2} m_n^2 (y_n,\omega)\right) \left| \frac{\partial m_n(y_n,\omega)}{\partial y_n} \right| \end{aligned} \tag{2.11}$$

The contribution of the n^{th} observation to the log-likelihood function $l(y,\omega)$ is the logarithm of (2.11)

$$l_n (y_n,\omega) = -\tfrac{1}{2} \ln (2\pi) - \tfrac{1}{2} m_n^2(y_n,\omega) + k_n(y_n,\omega) \tag{2.12}$$

where: $k_n (y_n,\omega) \equiv \ln \left| \frac{\partial m_n(y_n,\omega)}{\partial y_n} \right|$

Since all the observations are independent, the log-likelihood function itself is merely the sum of the contributions $l_n(y_n,\omega)$. The gradient of $l(y,\omega)$ is

$$g(y,\omega) = \left(-M'(y,\omega) \quad K'(y,\omega)\right) \begin{bmatrix} m(y,\omega) \\ \iota \end{bmatrix} \tag{2.13}$$

$$\text{where: } M_{ni}\,(y_n,\omega) \equiv \frac{\partial m_n(y_n,\omega)}{\partial \omega_i} \qquad K_{ni} \equiv \frac{\partial k_n(y_n,\omega)}{\partial \omega_i}$$

and $m(y,\omega)$ is an N vector with typical element $m_n(y,\omega)$ and ι denotes an N vector each element of which is 1.

Using this result we can construct the DLR, developed by Davidson and MacKinnon (1984). Artificial regressions are simply linear regressions that are used as calculating devices. The regressand and the regressors are constructed in such a way that when the artificial regression is run, certain of the numbers printed by the regression program are quantities which we want to compute. The DLR looks as follows:

$$\begin{bmatrix} m(y,\omega) \\ \iota \end{bmatrix} = \begin{bmatrix} -M(y,\omega) \\ K(y,\omega) \end{bmatrix} b + \text{residuals} \tag{2.14}$$

This artificial regression has 2N artificial observations. The regressand is $m_n(y,\omega)$ for observation n and unity for observation n+N, and the regressors corresponding to b are $-M_n(y,\omega)$ for observation n and $K_n(y,\omega)$ for observation n+N, where M_n and K_n denote, respectively, the n^{th} rows of M and K. We need a double-length regression because each observation makes two contributions to the log-likelihood function: a sum-of-squares term $-\frac{1}{2}\, m_n^2$ and a term k_n. The DLR can be estimated by OLS when an estimate for ω is available. If the artificial regression is evaluated at unrestricted ML estimates $\hat{\omega}$, the estimates of b are equal to:

$$\hat{b} = \left[\left(-M'(y,\hat{\omega})K'(y,\hat{\omega})\right) \begin{bmatrix} -M(y,\hat{\omega}) \\ K(y,\hat{\omega}) \end{bmatrix}\right]^{-1} \left(-M'(y,\hat{\omega})K'(y,\hat{\omega})\right) \begin{bmatrix} m(y,\hat{\omega}) \\ \iota \end{bmatrix} \tag{2.15}$$

The last product in this term is equal to the gradient of the log-likelihood function $l(y,\omega)$ evaluated at $\hat{\omega}$ and is therefore equal to zero. Therefore, the estimates of b are zero. Another possibility is to evaluate the DLR at restricted estimates of ω. As shown in Section 2.2, the functional forms are restrictions of the Box-Cox model. When a functional form is appropriate, the resulting estimates of b should also be close to zero. Davidson and MacKinnon (1984) show that an F-test is valid for testing the hypothesis that the coefficient on the regressors related to λ and τ are zero.

To make this result operational we derive the formulas of the variables in the DLR based on equation (2.1) (multiplied by σ). The first N elements of the regressand follow directly from equation (2.9). The regressors that correspond to u are

$$\begin{bmatrix} 1 \\ 0 \end{bmatrix} \tag{2.16}$$

where the upper and lower quantities inside the tall brackets denote, respectively the n^{th} and $(n + N)^{th}$ elements of the regressor. The regressors that correspond to α_i are

$$\begin{bmatrix} v_i\ (\lambda,\tau) \\ 0 \end{bmatrix} \tag{2.17}$$

The regressors corresponding to α_{ij}, β_i, β_{ij} and γ_{ij} are similar. The element of - $M(y,\omega)$ that corresponds to λ is:

$$\begin{aligned} &\sum_{i=1}^{2}\left[\ln v_i^*(v_i^*)^{\lambda}\right]\left\{\alpha_i+(\sum_{k=1}^{3}\theta_k v_k)^{\tau-1}\sum_{j=1}^{3}\alpha_{ij}v_j(\lambda,\tau)+\sum_{j=1}^{3}\gamma_{ij}c_j(\lambda)\right\} \\ &+(1-\tau)\left[\ln v_3^*(v_3^*)^{\lambda}\right]\left\{\alpha_3+(\sum_{k=1}^{3}\theta_k v_k)^{\tau-1}\sum_{j=1}^{3}\alpha_{3j}v_j(\lambda,\tau)+\sum_{j=1}^{3}\gamma_{3j}c_j(\lambda)\right\} \\ &+\sum_{j=1}^{3}\left[\ln c_j(c_i)^{\lambda}\right]\left\{\tau^2\beta_j+(\sum_{k=1}^{3}\theta_k v_k)^{1-\tau}\sum_{i=1}^{3}\beta_{ij}c_i(\lambda)+\sum_{i=1}^{3}\gamma_{ij}v_i(\lambda,\tau)\right\} \end{aligned} \tag{2.18}$$

The element of $K(y,\omega)$ that corresponds to λ is zero.

The regressor that corresponds to τ is:

$$\left[\begin{array}{c}
\ln v_3(\pi(\tau)) - \lambda \sum_{i=1}^{2} \left(\ln v_3(v_i(\lambda,\tau))\right) \left[\alpha_i + (\sum_{k=1}^{3} \theta_k v_k)^{\tau-1} \sum_{j=1}^{3} \alpha_{ij} v_j(\lambda,\tau) + \sum_{j=1}^{3} \gamma_{ij} c_j(\lambda,\tau) \right] - \\
\left((v_3^*)^{\lambda} - \tau + (1-\tau)(\lambda \ln v_3(v_3^*)^{\lambda} + 1)\right) \left[\alpha_3 + (\sum_{k=1}^{3} \theta_k v_k)^{\tau-1} \sum_{j=1}^{3} \alpha_{3j} v_j(\lambda,\tau) + \sum_{j=1}^{3} \gamma_{3j} c_j(\lambda,\tau) \right] \\
+ \frac{1}{2} \ln(\sum_{k=1}^{3} \theta_k v_k) \ [\ (\sum_{k=1}^{3} \theta_k v_k)^{\tau-1} \sum_{i=1}^{3} \sum_{j=1}^{3} \alpha_{ij} v_i(\lambda,\tau) v_j(\lambda,\tau) - \\
(\sum_{k=1}^{3} \theta_k v_k)^{1-\tau} \sum_{i=1}^{3} \sum_{j=1}^{3} \beta_{ij} c_i(\lambda) c_j(\lambda)\ ] + 2\tau \sum_{j=1}^{3} \beta_j c_j(\lambda) \\
- \sigma \ln v_3
\end{array}\right] \qquad (2.19)$$

The regressor that corresponds to σ is:

$$\begin{bmatrix} m_n(\pi_n(\delta, \epsilon, \tau), \omega) \ / \sigma \\ -1 \end{bmatrix} \qquad (2.20)$$

Using these results the regressors of the DLR for specific values of λ and τ can be calculated. (These calculations are available from the authors upon request.)

To summarise, the steps to be undertaken when using the test based on the DLR are:

i) Estimate the functional form using maximum likelihood. OLS gives the same estimates for α, β and γ, only the estimate of σ should be corrected.

ii) Construct the DLR using equations (2.9), (2.16)-(2.20).

iii) Check the correctness of the constructed DLR by running the DLR without the regressor corresponding to the parameters λ and τ. This regression should have no explanatory power if everything has been constructed correctly.

iv) Estimate the DLR using OLS.

v) Use the F-test to test the hypothesis that the coefficients on the regressor related to λ and τ are zero. If this hypothesis is not rejected the functional form is not rejected against the linear Box-Cox model and is therefore an acceptable simplification of that model.

Below, the DLR is also used for the tests described in Section 2.2, whenever simplifications of the linear Box-Cox model are involved. These tests are straightforward simplifications of the DLR test described in this section.

2.4 Data and Estimation

The data used cover the period 1970-1988 and were provided by the Agricultural Economic Research Institute (LEI). Data on specialised arable farms (farms with more than 80% of total output consisting of marketable crops) were selected from a stratified sample of Dutch farms which kept accounts of their farming for the LEI book keeping system. The data set used for estimation includes 3249 observations on 733 different farms (see Appendix I, table I.1 for a description of data and variability).

One output and two[3] variable input categories (pesticides and other inputs) are distinguished. Other inputs consists of services, fertilisers, seed and planting materials, purchased feed input, energy and other variable inputs. Fixed inputs are land, labour and capital. Land is measured in ares. Labour is measured in quality-corrected man-years, and includes family as well as hired labour. Capital includes capital invested in machinery and livestock and is measured at constant 1980 prices. Capital invested in buildings was not included, since it proved impossible to obtain a reliable value of buildings for all farms in the sample.

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[3] The profit function was also estimated using three categories of variable inputs : pesticides, nitrogenous fertiliser and other variable inputs. The results were not very different from those of this specification.

Tornqvist price indexes were calculated for the two composite netput categories (output and other input). Price indexes vary over the years but not over the farms, implying that differences in the composition of a netput or quality differences are reflected in the quantity (Cox and Wohlgenant 1986). Implicit quantity indexes were obtained as the ratio of value to the price index.

The prices of arable products are not known at the time decisions are made on planting and the use of variable inputs, so expected rather than realised output prices have to be used (Higgins 1986). Expected output prices were constructed by applying an AR(1) filter. About 50% of the crops grown in the Netherlands are under a market regulation and prices of these crops are stable over the years. Therefore, the assumption that expected prices are generated by an AR(1) process is not simplistic. Expected profit was defined as expected revenue (expected prices times quantity of output) minus total value of the actual use of variable inputs.

A time trend and corresponding cross-products were added to equation (2.1) in order to allow for technological change. The regressors in the DLR that correspond to these terms look similar to equation (2.17).

The availability of panel data was explicitly taken into account in the steps to be undertaken for the DLR. We take as a constant plus error term in the linear GBC

$$u_{ht} = u + \eta_h + e_{ht} \qquad h = 1....H,\ t = 1....T_h \tag{2.21}$$

where η_h is the specific effect (fixed or random) of farm h representing the effect of those variables peculiar to the h_{th} individual in more or less the same fashion over time. T_h is the number of years of records on farm h. Total number of observations is N. In Section 2.3 we introduced e_{ht} as a normally distributed variable with mean zero and variances σ^2. The mean of u_{ht} is assumed to be equal to u. For the SNQ function u should be equal to zero, this will be tested in the following section.

The steps to be undertaken for the DLR are adjusted:

i) In equations (2.6)-(2.8) a farm specific effect is introduced. We use the fixed effects transformation to estimate these equations. The random effects estimator is generally more efficient but makes the unrealistic assumption that the individual effects and the regressors are independent.

ii) Equation (2.16) for farm h of the DLR looks similar, but the upper quantity inside the bracket denote the ht^{th} observation. For every farm we get a dummy variable, which is equal to one for observations on this farm and zero elsewhere.

iii) and iv) Estimate the DLR by OLS after transforming the data. The transformation matrix consists of the usual fixed effects transformation matrix in the top left corner. The lower right corner is the identity matrix, the other elements are zero. So, the fixed effects transformation is only applied to the (1..N) observations; the remaining (N+1..2N) observations are transformed by the identity matrix. This transformation matrix is symmetric and idempotent. Therefore, the proof that this transformation is valid is similar to the proof given by Hsiao (1986: 31-32) for the fixed effects transformation.

v) Use F and t tests and correct for the decrease in degrees of freedom due to the fixed effect estimation.

We developed the DLR for one equation. To increase the efficiency of parameter estimates we estimate the profit functions along with the netput equations (given in Appendix VII) for the calculation of price elasticities and elasticities of intensity.

The Iterative SUR estimation technique is applied here because the disturbance terms may be correlated across equations and because of the cross-equation parameter restrictions. In all cases we dropped the equation of other input in order to ensure non-singularity. The results of the NQ, SNQ and GL are not invariant with respect to the equation deleted. Error terms like equation (2.21) are also integrated into these systems. Thijssen (1992) shows that the common fixed effects transformation can also be applied to an incomplete panel, using a SUR estimation method.

2.5 Results

2.5.1 DLR Test

In order to use the DLR approach we performed steps i-v as described in Sections 2.3

and 2.4. For every functional form, the explanatory power of the DLR was checked in a separate regression without the terms corresponding to λ and τ. In these regressions, all the estimates of the parameters were very small and t values were zero, and therefore the condition in step iii was satisfied. The parameter restrictions of the SNQ (see section 2.2) were also imposed at this stage and at the following stage, since they follow immediately from (2.17). The F values of step v are given in the first row of Table 2.2.

The test against the generalised linear Box-Cox model reveals that all functional forms are rejected at the critical 5% level, since all F values are larger than $F_{2,5635,\acute{o}=0.05}$ (=3.00). The F value for the NQ is however close to the critical 1% level (of 4.61). As pointed out in Section 2.2, these test results imply that the transformation applied (through λ and τ) and linear homogeneity are simultaneously rejected, i.e. it does not necessarily imply that the specific transformation through λ is rejected. Linear homogeneity, conditional on the transformation (see Section 2.2), is tested by a t test on the parameter of the regressor corresponding to τ in the DLR (equation 2.19). The test of linear homogeneity of the GL, NQ and SNQ points out that linear homogeneity is rejected (at 5%) for the GL and SNQ, but not for the NQ.

Table 2.2: Results of the DLR : F and t-values of nested hypotheses.

Test	GL	NQ	SNQ
Linear GBC	37.43	5.00	9.54
Linear Homogeneity	2.05	0.58*	4.28

* not significant at the 5% level

2.5.2 Regularity Conditions and other Criteria

In addition to testing the three functional forms against the linear GBC, they are also evaluated in terms of regularity conditions, parameter significance, and elasticities of prices and intensity. The regularity conditions of the profit function are convexity in prices, monotonicity (increasing in output prices, decreasing in input prices) and increasing in fixed inputs. Table 2.3 shows that the GL violates convexity in prices for approximately half the number of observations; convexity is not violated for the NQ and SNQ at any observation. Monotonicity in prices is slightly violated for all functional forms. In previous empirical studies, the condition of convexity in prices was often violated, so our results are not unusual. The monotonicity condition has also rarely been violated in previous empirical work. For an overview and interesting discussion on evaluation of regularity conditions, see Fox and Kivanda (1994) and the related comments.

The SNQ performs very poorly in terms of the condition that the function is increasing in fixed inputs. Given that its performance in the other tests in this table, including the percentage of significant parameters, is good, this is surprising.

Table 2.3 : Evaluation of regularity conditions and parameter significance.

	percent of violations			
FFF	convexity in prices[1]	monotonicity[2]	increasing in fixed inputs[2]	percent of parameters significant at 5%
GL	43.39	0.61	4.86	62.96
NQ	0	0.12	0.09	59.25
SNQ	0	0.15	62.01	57.14

1) Convexity was checked by the determinantal test of the hessian. The GL was checked at each observation since their hessians are not constant.

2) Monotonicity and increasing in fixed inputs were rejected if this condition failed to hold for at least one netput or fixed input. The percentage of violations would have been lower if calculated as percentage of total number of netputs or fixed inputs.

In section 2.4 we have demonstrated that the SNQ is only linearly homogeneous in prices when the error component u is zero. This error component can be determined by calculating the mean of all composite error terms from the profit function. The value of u from the ITSUR estimation was found to be -26770, with a t value of 0.37. From this we infer that u is not significantly different from zero (at 5%) and linear homogeneity of the SNQ is not violated by using a fixed effects model.

Table 2.4 : Price elasticities at the sample mean (estimated standard deviation in parentheses).

		price of		
		output	pesticides	other input
output	GL	0.02 (0.03)	-0.01 (0.00)	-0.04 (0.03)
	NQ	0.05 (0.02)	-0.00 (0.00)	-0.05 (0.02)
	SNQ	0.10 (0.03)	-0.01 (0.00)	-0.11 (0.03)
pesticides	GL	0.07 (0.03)	-0.46 (0.09)	0.40 (0.10)
	NQ	0.06 (0.03)	-0.24 (0.08)	0.18 (0.09)
	SNQ	-0.09 (0.03)	-0.55 (0.11)	0.64 (0.12)
other input	GL	0.06 (0.08)	0.09 (0.02)	-0.15 (0.09)
	NQ	0.06 (0.08)	0.04 (0.02)	-0.20 (0.08)
	SNQ	0.33 (0.09)	0.14 (0.03)	-0.47 (0.09)

Table 2.4 shows the price elasticities (see Appendix I, table I.2 for their expressions) that were calculated from the estimated parameters at the sample mean. The price effects are small in general, especially those that relate to the output. This reflects the crop rotation restrictions in Dutch arable farming, and also the restricted availability

of land. Pesticides are found to be gross substitutes with respect to other input. Most price elasticities correspond well, although some large differences are found between the SNQ and NQ for pesticides with respect to its own price and the price of other input; the same holds for the own price elasticity of other input.

The elasticities of intensity (see Appendix I, table I.2 for their expression) are presented in Table 2.5. The SNQ reveals that capital is a substitute for pesticides and the GL reveals that labour is a substitute for other input. In addition, all other relations between fixed inputs and variable inputs are characterised by complementarity. Large differences are mainly found between the SNQ and GL for output with respect to land and for other input with respect to labour and capital.

Table 2.5: Elasticities of intensity at the sample mean (estimated standard deviation in parentheses).

		amount of			
		land	labour	capital	trend
output	GL	0.43 (0.02)	0.33 (0.02)	0.14 (0.01)	0.02 (0.07)
	NQ	0.50 (0.02)	0.38 (0.02)	0.22 (0.02)	0.03 (0.00)
	SNQ	0.83 (0.03)	0.26 (0.03)	0.11 (0.02)	0.03 (0.00)
pesti-	GL	0.94 (0.06)	0.15 (0.04)	0.14 (0.03)	0.05 (0.03)
cides	NQ	0.80 (0.05)	0.14 (0.03)	0.13 (0.02)	0.05 (0.00)
	SNQ	0.01 (0.06)	0.08 (0.04)	-0.05 (0.03)	0.03 (0.08)
other	GL	0.53 (0.14)	-0.04 (0.10)	0.07 (0.07)	-0.04 (0.07)
input	NQ	0.69 (0.08)	0.15 (0.05)	0.25 (0.04)	-0.00 (0.00)
	SNQ	0.70 (0.15)	0.59 (0.12)	0.41 (0.09)	0.01 (0.02)

2.6 Discussion and conclusions

This chapter uses the Generalised Box-Cox framework and Double Length artificial Regression to test whether different linear specifications of the profit function are able to mimic the technology underlying panel data of Dutch arable farms for the period 1970-1988. Functional form results are also evaluated in terms of regularity conditions, parameter significance and reasonability of elasticities.

The NQ and SNQ were included explicitly in the linear GBC and a test based on DLR was used in order to avoid cumbersome estimation of the linear GBC. The test based on DLR rejected all functional forms against the linear GBC, the F values of the NQ were much lower, however. The proposed test on linear homogeneity comes out in favour of the NQ.

The NQ also outperforms all other forms on the regularity conditions that were examined. The GL violates convexity in prices for approximately half the number of observations, whereas the SNQ is often non-increasing in fixed inputs. Also, the price elasticity estimates of the FFFs were in accordance with neo-classical theory. However, large differences between price elasticities within the class of linear FFFs are found between the NQ and SNQ. This reflects a serious shortcoming of the NQ, namely that estimation results are not invariant with respect to the choice of the numeraire.

Testing the three functional forms against the linear GBC using DLR allows the data to tell what functional form is preferred and avoids estimating the linear GBC. Moreover useful simplifications can easily be made within the linear GBC and tested using DLR.

Chapter 3
Effects of input quotas in Dutch arable farming

Summary

The effects of a hypothetical introduction of a quota on pesticides are analysed using a short-term profit function which is derived from duality theory. A normalised quadratic function is estimated using panel data from Dutch arable farms over the period 1970-1988.

Price elasticities and elasticities of intensity are calculated before and after the introduction of the quota. The effects on price elasticities are small in general. Fixed inputs show an increasing or decreasing complementarity depending upon the previous relation between the variable and former variable input (pesticides).

The shadow price of pesticides will rise by about 85% above the previous market price due to a 10% cut in the pesticide quota. Shadow prices of fixed inputs decrease after the hypothetical introduction due to complementarity with pesticides.

3.1 Introduction

Environmental measures and agricultural policy are sources of an increasing number of restrictions on agricultural production. A case of present interest in Dutch agriculture is the Long-term Crop Protection Plan (LCPP) which aims among other things to lower the average 1984-1988 level of pesticide use. About two third of those pesticides are used in arable farming. Targeted reductions for this sector - measured in terms of active ingredient - are 39% in 1995 and 60% by 2000 (MJP-G, 1991 : 101). Besides this, the government aims at reducing the flow of nitrates and phosphates to the environment.

These plans can be translated into various measures. Taxes, subsidies and quantitative restrictions are among the most commonly used instruments (Baumol and Oates, 1988). When introducing combined tax/quota policies, one should take into account that price elasticities are affected by the introduction of the quota (Guyomard and Mahé

(1993) and Fulginiti and Perrin (1993)). The same holds for shadow prices of a priori fixed inputs and elasticities of intensity.

Helming et al. (1993) evaluated these effects in the case of milk quota by using data before and after the introduction of quotas. Fulginiti and Perrin (1993) and Guyomard and Mahé (1993), however, showed that the parameters of a restricted profit function (after a quota) can be determined with those of an unrestricted (before quota) one, when only the latter are known and vice versa. This study applies the latter methodology to micro data in order to determine the effects of a hypothetical introduction of a pesticides quota on price elasticities, elasticities of intensity and shadow prices of fixed inputs and pesticides. Furthermore the methodology will be illustrated through simulations with four different policy options.

The structure of this chapter is as follows. The theoretical and empirical models are discussed in section 3.2 and 3.3, respectively. Section 3.4 describes the estimation procedure and the data used for this research, while the estimation results and the analysis for the pesticides quota are presented in section 3.5. The application with four policy options are discussed in section 3.6 and the chapter concludes with comments on this research.

3.2 Theoretical model

Neoclassical production theory forms the framework for our analysis of the effects of quantitative restrictions and taxes on detrimental inputs. The theory is more widely discussed in Chambers (1988) and will only briefly be surveyed here. This section will concentrate on the theory underlying the determination of restricted price elasticities and shadow prices after a hypothetical introduction of a quota from the parameters of an unconstrained profit function.

To begin, it is assumed that all inputs and outputs, or more compactly "netputs", are freely disposable (variable). Profit maximisation conditional on a convex production possibility set or technology T can be denoted as :

$$\pi(v) = \max_{q} \{v.q;\ (q)\epsilon T;\ v > 0\} \tag{3.1}$$

where q is a vector of netput quantities (negative for inputs, positive for outputs) and v a vector of netput prices. The profit function π is assumed to be non-negative, non-decreasing in output prices, non-increasing in input prices, convex and linearly homogeneous in prices, continuous and twice differentiable.

Applying Hotelling's lemma to (3.1) yields the optimal level of netputs as a function of v:

$$\pi_v = q(v) \tag{3.2}$$

where π_v is the vector of first derivatives of π with respect to v.

Next the netput vector q is partitioned into vectors q_1 and q_2, where q_1 is, as before, a vector of freely disposable netputs, but where q_2 is now a vector of fixed netputs (or equivalently, netputs which are under a quota). v_1 and v_2 are the corresponding price vectors. Furthermore, G represents the general restricted profit function (McFadden, 1978 : 66) which incorporates the fixed quantity q_2 :

$$G(v_1,q_2) = \max_{q_1} \{v_1.q_1;\ \ (q_1,q_2)\epsilon\ T;\ v_1 > 0\} \tag{3.3}$$

G has the same properties as π except that it is not necessarily non-negative and besides that, it is decreasing in quantities of fixed netputs. Note that G includes the more familiar cost (revenue) functions as special cases, that is when q_1 is a vector of input (output) quantities and q_2 a vector of output (input) quantities. Applying Hotelling's Lemma to (3.3) yields optimal levels of q_1, now as a function of v_1 and q_2 :

$$G_{v_1} = q_1(v_1, q_2) \tag{3.4}$$

where G_{v1} denotes the first derivative of G with respect to v_1. An intuitive explanation of q_2 is that of a vector of netputs, which are fixed in the short term, but variable in the long term. In that case π can be regarded as a long-term profit function, which can also be seen by expressing (3.1) as :

$$\pi(v) = \max_{q_2} \{v_2.q_2 + G(v_1,q_2);\ (q_1, q_2)\epsilon T;\ v_1,v_2>0\} \tag{3.5}$$

(3.5) implies profit maximisation over the remaining vector q_2 given that q_1 is at the optimal level. This can be made more explicit by differentiating (3.5) with respect to v_1 and v_2 [1]:

$$\pi_{v_1} = q_1(v_1, q_2(v_1, v_2)) \tag{3.6}$$

$$\pi_{v_2} = q_2(v_1, v_2) \tag{3.7}$$

These results can be used to express the Hessian of the restricted profit function (G) in terms of the unconstrained Hessian of π (Fulginiti and Perrin (1993) and Guyomard and Mahé (1993))[2].

Defining $\pi_{v_1 v_2}$ as the matrix of second partial derivatives of π with respect to v_1 and v_2,

then by differentiating (3.6) with respect to v_2 and using (3.4) and (3.7) it can be expressed as:

$$\pi_{v_1 v_2} = G_{v_1 q_2} \cdot \pi_{v_2 v_2} \tag{3.8}$$

which yields after rewriting :

$$G_{v_1 q_2} = \pi_{v_1 v_2} \cdot (\pi_{v_2 v_2})^{-1} \tag{3.9}$$

Similarly differentiating (3.6) with respect to v_1 and using (3.4) and (3.7) results in :

$$\pi_{v_1 v_1} = G_{v_1 v_1} + G_{v_1 q_2} \cdot \pi_{v_2 v_1} \tag{3.10}$$

Which can be rewritten by inserting (3.9) into (3.10) to solve for $G_{v_1 v_1}$:

$$G_{v_1 v_1} = \pi_{v_1 v_1} - \pi_{v_1 v_2} \cdot (\pi_{v_2 v_2})^{-1} \cdot \pi_{v_2 v_1} \tag{3.11}$$

It follows from (3.11) that constrained own-price effects (the elements of G_{v1v1}) are smaller than or equal to the elements of π_{v1v1}, because all matrices on the RHS of (3.11)

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1 Note that (3.6) and (3.7) are the same as (3.2), since the vectors q and v were partitioned

2 Fulginiti and Perrin (1993) and Guyomard and Mahé (1993) also show that it is possible to obtain the unconstrained Hessian when the Hessian of G is known.

are positive semi-definite[3]. This result is more commonly known as the Le Chatelier-Samuelson effect (Chambers, 1988 : 134). For the off-diagonal elements of G_{v1v1}, it has been shown that restricting one netput (in which case π_{v2v2} is 1x1) will increase substitutability and reduce complementarity (Guyomard and Mahé, 1993). The second term on the RHS of (3.11) is also referred to as the indirect effect, whereas the term on the LHS of (3.11) is usually called the direct effect (Moschini, 1988).

The quantity of a fixed netput in the vector q_2 has a value for the producer, that is called the shadow price. The vector of shadow prices of the fixed netputs is determined as minus the first derivative of G with respect to q_2 :

$$v^s = -G_{q_2} \tag{3.12}$$

Essentially, the shadow price equals marginal cost in the case of outputs, and marginal revenue product in the case of inputs; Furthermore, the shadow price is equal to the market price when the netput is freely disposable and the producer is maximising profit. Figure 1 gives a graphical representation of the effects of an introduction of a quota on the shadow price of a formerly freely disposable input. It follows that the shadow price (v_{2i}^s) depends upon the severeness of the restriction and the slope of the marginal revenue product curve (which equals $1/\pi_{v2iv2i}$ under the assumption of a linear marginal revenue product curve). A relaxation of the constraint lowers the shadow price of an input. The shadow price of an input will be at least as high as its market price v_{2i}^m whenever the quota is binding.

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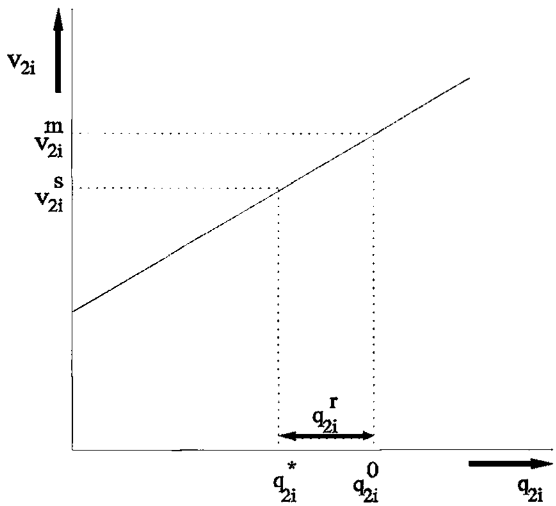
3 Positive semi-definiteness of the Hessian follows from convexity of the profit function in prices.

Figure 1 : Shadow price and quota level for netput q_{2i}



The future shadow price of an netput can easily be read of from Figure 1. When it is assumed that quota level (q_{2i}^*) is set below the optimal level (q_{2i}^o) by a (negative) amount of q_{2i}^r , then the shadow price is approximated as :

$$v_{2i}^s = v_{2i}^m + \frac{q_{2i}^r}{\pi_{v_{2i}v_{2i}}} \tag{3.13}$$

Including a vector of fixed netputs in (3.5), prior to the introduction of a quota, does not change the results of this section. Furthermore, a similar result as for the price elasticities holds for the elasticities of intensity under a quota (see Appendix VIII).

3.3 Empirical model

The preceding section presented a method for obtaining price elasticities in a situation where one or more netputs is restricted from those under unconstrained profit maximisation. This section will translate this theoretical model into an estimable form. In order to calculate the effect of a combined pesticide quota and N-fertiliser tax, the price elasticities which hold under a quota on pesticides are needed.
The Normalised Quadratic is the functional form that is used in this chapter, because it overall came out more favourable than the other functional forms that were tested in Chapter 2. Other reasons for choosing the Normalised Quadratic are its simplicity and the fact that it has a hessian of constants implying that convexity in prices can be tested globally. The Normalised Quadratic takes the form :

$$\begin{aligned}\pi = {} & \alpha_0 + \sum_{i=1}^{3} \alpha_i v_i + \sum_{j=1}^{3} \beta_j z_j + \tau_t t + \omega_w w + \frac{1}{2}\sum_{i=1}^{3}\sum_{j=1}^{3} \alpha_{ij} v_i v_j \\ & + \frac{1}{2}\sum_{j=1}^{3}\sum_{i=1}^{3} \beta_{ij} z_i z_j + \frac{1}{2}\tau_{tt} t^2 + \frac{1}{2}\omega_{ww} w^2 + \sum_{i=1}^{3}\sum_{j=1}^{3} \rho_{ij} v_i z_j + \\ & \sum_{i=1}^{3} \tau_{vi} v_i t \sum_{i=1}^{3} \omega_{vi} v_i w + \sum_{j=1}^{3} \tau_{zj} z_j t + \sum_{j=1}^{3} \omega_{zj} z_j w\end{aligned} \tag{3.14}$$

where π is normalised variable profit[4], v_i are normalised netput prices, with i=1 (output), 2 (pesticides) and 3 (nitrogenous fertiliser). Furthermore, z_i are fixed inputs with i=1, (land), 2 (labour) and 3 (capital). Finally, technological change is represented by a time trend (t), and w represents a weather index. Symmetry is imposed by requiring $\alpha_{ij}=\alpha_{ji}$ and $\beta_{ij}=\beta_{ji}$, for all i and j.

The output supply and input demand equations are obtained by differentiating (3.14) with respect to the vector of normalised prices :

4 All prices and profit have been normalised by the price of other variable inputs. This ensures linear homogeneity in prices.

$$y_i = \alpha_i + \sum_{j=1}^{3} \alpha_{ij} v_j + \sum_{j=1}^{3} \rho_{ij} z_j + \tau_{vi} t + \omega_{vi} w \tag{3.15}$$

where y_i are netput quantities corresponding to the netput prices. The (Marshallian) netput price elasticities (ϵ_{ij}), the elasticities of intensity of netput i with respect to fixed input j (ϵ_{iz_j}) [5], and the shadow prices of fixed inputs (v^s_{zi}), are derived from the estimated parameters of the profit function in the following way:

$$\epsilon_{ij} = \alpha_{ij} \cdot \frac{v_j}{y_i} \quad i,j=1,2,3 \tag{3.16}$$

$$\epsilon_{iz_j} = \rho_{ij} \cdot \frac{z_j}{y_i} \quad i,j=1,2,3 \tag{3.17}$$

$$v^s_{zi} = \beta_i + \sum_{j=1}^{3} \beta_{ij} z_j + \sum_{j=1}^{3} \rho_{ji} v_j + \tau_{zi} t + \omega_{zi} w \quad i=1,2,3 \tag{3.18}$$

The contribution of technological development to profit is calculated in a similar way as (3.18) :

$$v^s_{zt} = \tau_t + \tau_{tt} . t + \sum_{j=1}^{3} \tau_{zj} . z_j + \sum_{j=1}^{3} \tau_{vj} v_j \tag{3.19}$$

Elasticities of the numéraire input can be derived by using the definition of the other input ($y_4 = \pi - v_1 . y_1 - v_2 . y_2 - v_3 . y_3$).

[5] The price elasticity ϵ_{ij} (elasticity of intensity ϵ_{iz}) measures the percentage change of netput quantity i as a result of a 1% change of netput price j (quantity of quasi-fixed input j).

$$y_4 = \alpha_0 + \sum_{j=1}^{3} \beta_j z_j + \tau_t t + \omega_w w - \frac{1}{2}\sum_{i=1}^{3}\sum_{j=1}^{3} \alpha_{ij} v_i v_j + \frac{1}{2}\sum_{j=1}^{3}\sum_{i=1}^{3} \beta_{ij} z_i z_j$$
$$+ \frac{1}{2}\tau_{tt} t^2 + \frac{1}{2}\omega_{ww} w^2 + \sum_{j=1}^{3} \tau_{zj} z_j t + \sum_{j=1}^{3} \omega_{zj} z_j w \tag{3.20}$$

Next the pesticide quota is introduced and it is assumed that producers are faced with a 10% cut in pesticides use at the onset of the quota regime. The effects on the price elasticities and elasticities of intensities will then be twofold. The first effect will be the change in the parameters of the profit function (see section 3.2), whereas the second effect comes from the change in the quantities of netputs due to the quota reduction. New netput quantities (y_i^*) are calculated with the elasticity of intensity of the remaining netputs with respect to the quantity of pesticides (ϵ_{iy_2}) , using (3.9) :

$$\epsilon_{iy_2} = \frac{\alpha_{2i}}{\alpha_{22}} \cdot \frac{y_2}{y_i} \qquad i=1,3 \tag{3.21}$$

Netput prices and fixed inputs are assumed not to change, since prices are exogenous and because this model is only capable of determining short-term effects, respectively.

The pesticide (netput 2) restricted netput price elasticities (ϵ^r_{ij}) and elasticities of intensity $(\epsilon^r_{z_j})$ are calculated in the following way :

$$\epsilon^r_{ij} = (\alpha_{ij} - \frac{\alpha_{2i}}{\alpha_{22}} \cdot \alpha_{j2}) \cdot \frac{v_j}{y_i^*} \quad i=1,3 \quad j=1,3 \tag{3.22}$$

$$\epsilon^r_{iz_j} = (\rho_{ij} - \frac{\alpha_{i2}}{\alpha_{22}} \cdot \rho_{2j}) \cdot \frac{z_j}{y_i^*} \quad i=1,3 \quad j=1,2,3 \tag{3.23}$$

Finally the shadow price of pesticides after the 10% cut is :

$$v_2^s = v_2^m \cdot (1 + \frac{0.1}{\epsilon_{22}}) \qquad (3.24)$$

Shadow prices of fixed inputs after the quota introduction are calculated by inserting the shadow price of pesticides (from (3.24)) instead of v_2 into (3.18) and (3.19) (Appendix VIII).

3.4 Data and estimation

The data used cover the period 1970-1988 and were provided by the Agricultural Economic Research Institute (LEI). Data of specialised arable farms (farms with more than 80% of total output consisting of marketable crops) were selected from a stratified sample of Dutch farms which kept accounts of their farming on behalf of the LEI book accounting system.

One output and three variable input categories (pesticides, N-fertiliser and other inputs) are distinguished (see section 3.3). Other inputs consists of services, non-nitrogenous fertiliser, seed and planting materials, purchased feed input, energy and other variable inputs. Fixed inputs are land, labour and capital. Land is measured in ares. Labour is measured in quality-corrected man-years, and includes family as well as hired labour. Capital includes capital invested in machinery and livestock and is measured at constant 1980 prices. Capital invested in buildings was not included since it proved impossible to obtain a reliable value of buildings for all farms in the sample (Elhorst, 1990 : 84).

Törnqvist price indexes are calculated for the two composite netput categories (output and other inputs). Implicit quantity indexes were obtained as the ratio of value to the price index. Price indexes vary over the years but not over the farms, implying that differences in the composition of a netput or quality differences are reflected in the quantity (Cox and Wohlgenant 1986). Output prices are not known at the time decisions are made on planting and the use of variable inputs, so expected rather than realised output prices have to be used (Higgins 1986, Weaver 1983). Expected output prices were constructed by applying an AR(1) filter. Expected profit was defined as expected revenue (expected prices times quantity of output) minus total value of the actual use of variable inputs. The weather index used is a weighted index of marketable crops and was calculated as the annual deviation of actual from systematic yield, such that 'average' weather yields a unit weather index (Oskam, 1991).

The profit functions are estimated along with the netput equations[6] in order to increase efficiency. Disturbance terms are added to these to take account of misspecification, measurement errors in dependent variables and optimisation errors. Because the disturbance terms may be correlated across equations, ITSUR is an appropriate estimation technique. This estimator converges to the Maximum Likelihood estimator and iterates the covariance matrix until it stabilises (Magnus, 1978). Every farm is assumed to have a different intercept reflecting differences in farm characteristics. This assumption is explicitly accounted for by estimating a fixed effects model, that can also be applied to an incomplete panel (Thijssen, 1992).

3.5 Estimation results

The parameter estimates and (corrected for fixed effects) standard errors can be found in Appendix II (Table II.2). 53% of all parameters are significant at the 5% critical level. Convexity in prices was checked by the eigenvalue test (Lau, 1978 : 447) and was not violated[7]. This implies that the Normalised Quadratic will be convex over the whole range of observations, since it has a Hessian of constants.

The price elasticities that were obtained from the parameter estimates and the values of the dependent variables at the sample mean (see Appendix II, table II.1), are presented in Table 3.1. The price elasticities that relate to the output are generally small. The own-price elasticity of pesticides of -0.12 is smaller than an earlier finding on aggregate data of the LEI book accounting system of -0.21 (Oskam et al. 1992 : 69). The own-price elasticity of N-fertiliser of -0.43 is often found in this range in the literature (see Burrell 1989). Pesticides and N-fertiliser are found to be gross complements, whereas pesticides and N-fertiliser are gross substitutes with respect to other inputs.

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[6] One equation has to be deleted in order to insure non-singularity of the covariance matrix.

[7] A sufficiënt condition for quasi-convexity of an *nxn* matrix is that the number of nonnegative eigenvalues be greater than or equal to *(n-1)x(n-1)* (Lau, 1978 :417)

Table 3.1 : Price elasticities and elasticities of intensity before the hypothetical pesticide quota introduction (estimated standard error in parentheses)

	price elasticities				elasticities of intensity			
	Output	Pesticides	N-fertiliser	Other inputs	Land	Labour	Capital	Trend
Output	0.08	-0.00	-0.00	-0.08	0.53	0.28	0.14	0.02
	(0.02)	(0.00)	(0.00)	(0.02)	(0.02)	(0.02)	(0.02)	(0.00)
Pesticides	0.08	-0.12	-0.02	0.06	0.78	0.08	0.14	0.05
	(0.03)	(0.08)	(0.05)	(0.08)	(0.05)	(0.03)	(0.02)	(0.00)
N-fertiliser	0.09	-0.05	-0.43	0.39	0.85	0.03	0.08	0.01
	(0.06)	(0.14)	(0.16)	(0.21)	(0.09)	(0.06)	(0.05)	(0.01)
Other inputs	0.27	0.02	0.03	-0.32	0.66	0.17	0.25	-0.01
	(0.08)	(0.02)	(0.02)	(0.08)	(0.10)	(0.07)	(0.05)	(0.01)

The elasticities of intensity indicate complementarity between all variable inputs and fixed inputs. Output supply and input demand are most heavily affected by variations in land. The elasticities of intensity that relate to the output can be considered as production elasticities given that variable inputs can be adapted freely to the optimal level at the same time. Technological development encourages the use of pesticides and N-fertiliser, but reduces the use of other inputs. Most elasticities are found to be significant at the critical 5% level.

The restricted price elasticities and elasticities of intensity after the hypothetical introduction, and 10% reduction, of the pesticide quota are presented in Table 3.2. At first sight, most price elasticities have not been affected at all. Moreover, some effects of the pesticide quota on the price elasticities do not seem to conform to the theoretical results in Section 3.3. For example, the own price elasticity of N-fertiliser has increased, whereas a decrease was expected according to the Le Chatelier-Samuelson effect. This is because netput quantities have changed after the introduction of the pesticide quota. The effects on price elasticities are theoretically correct and more pronounced when evaluated at the original values of netput quantities[8].

Table 3.2 : Restricted price elasticities and elasticities of intensity after the hypothetical introduction of a pesticides quota and a subsequent 10% cut (estimated standard errors in parentheses[9]).

	price elasticities			elasticities of intensity				
	Output	N-fer-tiliser	Other inputs	Land	Labour	Capital	*Pesticides*	Trend
Output	0.08	-0.00	-0.08	0.51	0.28	0.14	0.04	0.02
	(0.02)	(0.00)	(0.03)	(0.04)	(0.02)	(0.02)	(0.03)	(0.00)
N-ferti-liser	0.06	-0.44	0.38	0.49	-0.01	0.01	0.31	-0.01
	(0.11)	(0.18)	(0.19)	(1.01)	(0.12)	(0.19)	(1.15)	(0.07)
Other inputs	0.27	0.03	-0.31	0.75	0.18	0.27	-0.10	-0.00
	(0.09)	(0.02)	(0.07)	(0.16)	(0.07)	(0:06)	(0.13)	(0.01)

The elasticities of intensity that relate to N-fertiliser have been affected most by the quota introduction. Under the pesticide quota, labour has become a substitute for N-fertiliser, while the complementarity of land and capital with N-fertiliser has sharply decreased. On the other hand, the complementarity of fixed inputs with other inputs has increased. These contrary effects must be explained by their relation with pesticides. Complementarity (substitutability) with fixed inputs increases (decreases) when a netput is a substitute for pesticides (like other inputs), while it decreases (increases) when it is a complement (N-fertiliser). The shift from complements to substitutes in case of labour indicates that N-fertiliser needs the free disposability of pesticides in order to be a complement of labour.

8 Provided that the pesticide quota is still binding at this level.

9 Standard errors (σ) were calculated by the following formala : $\sigma = (f' \; \Omega \; f)^{0.5}$, where f is a column vector of partial derivatives of the variance function with respect to the parameters of the profit function and Ω is the covariance matrix.

An aspect that should not be overlooked, is the fact that some elasticities (especially those of N-fertiliser) have become insignificant (at 5%). This means that less weight can be given to these results when used for simulation.

The shadow prices of fixed inputs (Table 3.3) in the unconstrained case are in line with a priori expectations. The average price of renting one hectare of arable land in 1980 was 440 guilders (LEI/CBS, 1992 : 132), however there is rent control in the Netherlands. Average hourly earnings in crop and livestock production mounted to 17.53 guilders in 1980 (LEI/CBS, 1992 : 128). The average yearly cost of an employee who works 40 hours/week can then be computed as 36462 guilders, which is close to the shadow price of labour. The shadow price of capital should be sufficient to pay interest, machinery maintenance and insurance. Therefore a value of about 0.12, which is somewhat lower than our finding of 0.13, was expected.

Table 3.3 : Shadow prices of fixed inputs and pesticides, before and after the hypothetical introduction of, and a subsequent 10% cut in, the pesticides quota in guilders of 1980 (estimated standard errors in parentheses).

variable	dimension	value before	value after
land	guilders/hectare	1683	1399
		(214)	(217)
labour	guilders/manyear	41624	40706
		(4893)	(4917)
capital	guilders/guilder	0.13	0.11
		(0.05)	(0.05)
annual shift	guilders/year	7559	6595
		(922)	(928)
pesticides	guilders/kilo of	*24.55*[a]	45.35[b]
	active ingredient		(8.57)

a) By definition, the shadow price of pesticides is equal to its market price before the quota introduction.

b) The average market price of pesticides in this data set is calculated from a price of 25.60 guilders per kilo of active ingredient (Oskam et al. 1992 : 11)

The shadow price of pesticides rises to almost 85% above the pre-quota market price when the pesticide quota is cut by 10 percent. This means that, on average, farmers are willing to pay approximately 85% of the market price for the opportunity to use an additional unit of pesticides, at this quota level. This also means that a 85% ad valorem tax on pesticides would result into the same (10%) reduction of pesticides use. Of all fixed inputs, land faces the sharpest relative decrease in the shadow price following a 10% cut in the pesticide quota. This is not very surprising given the high (in absolute terms) value of ρ_{2j} (since the change in the shadow price of fixed input j is calculated as ρ_{2j} times the change in the shadow price of pesticides). It can be seen that complementarity with pesticides leads to a decrease in the shadow price of the fixed inputs. If one fixed input had been a substitute for pesticides, then the opposite would have occurred for that input.

3.6 Effects of four policy options

This section will use the model and methodology, presented in the preceding sections (and Appendix VIII) to determine the effects of four different policy options on netput quantities and income. A preference for a specific option is subject to several criteria. The first is the exact aim of the environmental policy; are pesticides and N-fertiliser considered to be equally harmful and what are the environmental effects of other inputs? Other criteria may be the weight of income effects and the question whether environmental policy can be an instrument for output control. The following policy options are investigated :

1) Pesticide quota (-10%)
2) Pesticide quota / N-fertiliser tax (-10% / 10%)
3) N-fertiliser quota (-10%)
4) N-fertiliser quota / pesticide tax (-10% / 10%)

The effects of these options are reported in Table 3.4. The pesticide quota contributes to the reduction of N-fertiliser in the absence of fertiliser reducing policy. Moreover, a 10% tax on N-fertiliser can achieve an additional 5% reduction of N-fertiliser use with relatively small effects on output and income. A perceived reduction of N-fertiliser use can be obtained with an N-fertiliser quota, with small effects on income and other *netputs*. An additional pesticides tax has small effects on netput quantities but reduces income by 1%. These two options are therefore not very suitable for environmental policy that aims to reduce pesticides to a greater extent than N-fertiliser. Their income effects are however smaller than those of the first two options.

A few remarks about the relevance of these results for policy makers are in order here. First, no account was taken of the effects of technological developments on the use of pesticides and N-fertiliser. Recent experience has shown that it can play a major role in reducing the use of nitrogen and pesticides. Second, it is not clear what should be considered as the reference level for input reduction. In this study, the sample mean was taken. Third, the approach that was followed in this study does not make a distinction between different types of farms; it gives the results for an average farm. Obviously, farms that use pesticides and N-fertiliser more intensively will be more severely hit by the environmental measures that were analysed in this study. Fourth, it was assumed in this study that pesticides and N-fertiliser are homogeneous products. In particular, for pesticides however, environmental policy is more directed towards specific applications and types of pesticides rather than the whole group. Finally, results would have been of greater interest if outputs had been disaggregated. The mutual effects of EC and environmental policy on output supply and input use could be included in that case.

Table 3.4 : Effects on netput quantities and profit[10] of four different policy options (percent change relative to their original level)

Policy option	Quantity				
	Output	Pesticides	N-fertiliser	Other inputs	Profit
1. Pesticide quota (-10%)	-0.44	-10.0	-5.09	+1.33	-0.94
2. Pesticide quota/N-fertiliser tax(-10% / 10%)	-0.45	-10.0	-9.92	+1.64	-1.37
3. N-fertiliser quota (-10%)	-0.05	-0.47	-10.0	+0.80	-0.09
4. N-fertiliser quota / pesticides tax(-10% /10%)	-0.10	-1.65	-10.0	+0.91	-1.09

3.7 Discussion and conclusions

The purpose of this research was to develop a model that can calculate the effects for Dutch arable farms of hypothetical quantitative restrictions. A Normalised Quadratic restricted profit function, estimated as a fixed effects model, was applied to the general theoretical framework that was presented in section 3.2. The estimation period was 1970-1988. The results were satisfactory, since a large number of parameters was significant at 5% and convexity was not violated.

A quota on pesticides in general had small effects on the own and cross price elasticities of the remaining netputs. Furthermore fixed inputs show an increased or decreased complementarity depending upon the previous relation between the variable and former variable input (pesticides). Substitutability (complementarity) with a fixed input will increase (decrease), when the variable input is a complement of pesticides, while the

10 See Appendix VIII for the calculation of profit effects.

reverse will occur when it is a substitute for pesticides. More specifically labour switched from complements into substitutes for N-fertiliser when a pesticides quota was introduced.

Shadow prices are calculated for fixed inputs and pesticides before and after the introduction of the pesticide quota. The shadow price of pesticides rises by about 85% above the previous market price due to a 10% cut in the pesticide quota. Shadow prices of fixed inputs decrease after the introduction due to complementarity with pesticides.

The policy options that were discussed have very different effects on netput quantities and profit. A 10% reduction in the use of pesticides can be achieved by a tax that raises the price of pesticides to the level of the shadow price (at a tax rate of 85%) or by introducing a quota that is subsequently cut by 10 percent. Such a quota, combined with an N-fertiliser tax can also achieve a substantial reduction in the use of N-fertiliser. Profit decreases by approximately 1% as a result of these measures. An N-fertiliser quota combined with a 10% pesticides tax has smaller effects on other netputs and profit and will be a suitable instrument for reducing the level of N-fertiliser only.

The methodology used can give some interesting insights into the short-term effects of a hypothetical introduction of input constraints. The producer was therefore assumed to be in an equilibrium given the availability of fixed inputs. In the long term however the assumption of short-term fixity is not very likely to hold and a dynamic approach is needed.

Chapter 4

Modelling the new EU cereals and oilseeds regime in the Netherlands

Summary

This chapter examines the regional, farm-specific and sectoral effects of the new CAP regime for cereals and oilseeds (CO) with a simulation model of Dutch arable farming. The model is estimated with panel data on Dutch arable farms over the period 1970-1992. Simulation results are aggregated for different farm classes and for the whole sector.

Simulation of the new CO regime shows a reduction in the output of CO crops and other outputs by respectively 8.9% and 0.4%. Production of rootcrops increases by 0.4%. Pesticide and N-fertiliser use fall by respectively 2.8% and 6.7% and profit by 2%. Most large farms react to the new CO regime by reducing the area of CO crops and participating in the set-aside arrangements. In aggregate, 2% of total arable area is set aside. However, the results differ strongly between groups of farms.

4.1 Introduction

In 1992, the European Union reduced the price support for cereals and abolished the deficiency payments for oilseeds. To compensate farmers for their income loss, subsidies per hectare were introduced. In the Netherlands the rate of the subsidy differs between low and high productivity regions. Farms growing more than 12.9 hectares of cereals and oilseeds (in the high productivity region) or 18.2 hectares (in the low productivity region) have two choices. First, they can accept the set-aside obligation[1], in which case they receive the area subsidy for their total planted area of cereals and oilseeds (CO crops) and set-aside premium for their set-aside land. Second, they can avoid the set-aside obligation by applying for area subsidies for 12.9 or 18.2 hectares according to their region. The 12.9 and 18.2 hectares are equivalent to 92 tonnes of cereals for the average farm in each region (see LNV, 1992).

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[1] In 1992 the set-aside obligation was 15%, it changed to 12% in 1995, and for the season 1995/1996 it will be 10%. We used 12% in the calculations.

Following the new CO regime, area and set-aside premiums are coupled to the area of cereals, oilseeds and pulses. The quantity of land set aside depends on the farmer's area of these crops. In previous research either one or both of these aspects have not been accounted for. Guyomard et al. (1993) analysed the new CO regime assuming that area premiums are either fully coupled or fully decoupled from price levels. Moreover, set-aside decisions were exogenous in their model. Jensen and Lind (1993) accounted for the fact that area and set-aside premiums are decoupled from price support, but they did not allow set-aside decisions to be endogenous in their model. The contribution of this chapter to the existing literature analysing the new CO regime is that both these aspects are accounted for. This is possible because the effects are examined at the level of the individual farm. The decision to participate in the set-aside programme is endogenous in our model and depends among other things on prices of inputs and outputs and the level of the area and set-aside premiums. Regional aspects of the new regulation are also taken into account as are environmental effects concerning the use of pesticides and N-fertiliser.

The reactions of arable farms in the Netherlands are examined using a simulation model consisting of equations that are estimated using panel data for Dutch arable farms. In the model there are three outputs: CO crops, rootcrops and other outputs; three variable inputs: pesticides, N-fertiliser and other inputs; two fixed inputs: labour and capital; and land. Although total land and land used for rootcrops are fixed, land can shift between CO crops and other outputs. All farms are allowed to have a different technology through farm-specific and regional parameters. Furthermore it is assumed that a change in one output price affects the production of the other two outputs only through adjustments in the allocation of fixed inputs over outputs, i.e. the technology is non-joint in variable inputs.
The results of the estimation are used in a simulation model that calculates the short-term effects of the new CO regime for the farms that are in the panel. Simulation results are aggregated for different classes of farms and for the sector as a whole.

In this chapter, the theoretical model is elaborated in section 4.2 and the data are discussed in section 4.3. The empirical model is presented in section 4.4, while section 4.5 offers a discussion of the simulations and simulation results. The chapter concludes with some comments.

4.2 Theoretical model

The theoretical model that serves as a base for the empirical model in section 4.4 starts with a profit function that is non-joint in variable inputs (Chambers and Just, 1989) from which a coherent set of output supply equations and input and area demand equations can be derived through three optimisation stages. In the first stage, the optimal quantity of inputs and outputs is determined, holding the area and fixed input allocations constant. The second stage comprises the optimisation of labour and capital and in the third and final stage, the optimal area allocated to outputs is determined. The non-jointness assumption implies that variable inputs are output-specific and land, capital and labour can be allocated to different outputs.

Stage 1

The output-specific profit functions under non-jointness in variable inputs are:

$$\pi_i = \max_{y_i, x_i} \{p_i . y_i - w . x_i ; (y_i, x_i, a_i, z_i) \epsilon T\} \qquad i = 1,..,3 \tag{4.1}$$

where π_i is output-specific profit; p_i the price of output i; w a vector of input prices; x_i a vector of variable inputs used for the production of output i, a_i and z_i are respectively the output-specific area and fixed inputs (labour and capital) used for output i and T is the production possibilities set. π_i is twice continuously differentiable, linearly homogeneous and convex in prices, increasing in fixed quantities and output prices and decreasing in input prices (Chambers, 1988: pp.124-126).

The total profit function is defined as the sum of all output-specific profit functions and is non-joint in variable inputs by definition.

$$\pi(p_1, .., p_3, w, a_1, .. a_3, z_1, .., z_3) = \sum_{i=1}^{3} \pi_i(p_i, w, a_i, z_i) \tag{4.2}$$

Stage 2

In the second stage, the optimal allocation of the fixed inputs z across the three activities is determined. It starts with the following maximisation problem:

$$\pi(p_1, .., p_3, w, a_1, .., a_3, z) = \max_{z_1, z_2, z_3} \sum_{i=1}^{3} \pi_i(p_i, w, a_i, z_i) \qquad s.t. \ \sum_{i=1}^{3} z_i = z \tag{4.3}$$

where z is the total availability of fixed inputs. The first-order conditions for an optimum are:

$$\frac{\partial \pi_1(p_1, w, a_1, z_1)}{\partial z_1} = \frac{\partial \pi_j(p_j, w, a_j, z_j)}{\partial z_j} \quad \forall j \neq 1 \quad s.t. \ \sum_{j=1}^{3} z_j = z \tag{4.4}$$

and imply that the shadow prices of the fixed inputs are equalised across the three activities (outputs). This optimisation yields the optimal allocation of the fixed inputs, z_i, as a function of all input and output prices, the output-specific areas and total availability of z.

$$z_i = z_i(p_1,..,p_3, w, a_1,..,a_3, z) \qquad i = 1,..,3 \tag{4.5}$$

Inserting (4.5) into (4.2) yields the expression on the LHS of (4.3). At this stage, land allocated to the three outputs is still assumed to be fixed.

Stage 3

At the third stage, land is allocated to the outputs. At the level of the individual farm, the area of rootcrops is always at a technologically-constrained maximum, because these crops give much higher gross margins per hectare than other crops do. Shadow prices of areas of rootcrops will therefore also be higher than those of the other outputs and CO crops. However, in general area can shift easily between other outputs and CO crops. The optimisation over land will therefore be somewhat different compared to the optimisation over fixed inputs, since land adjustments can only be made between CO crops and other outputs. The total area used for CO crops and other outputs, and the area of rootcrops, are held fixed in the short term. This third stage of the optimisation has the following form:

$$\pi(p_1,..,p_3,w,a,a_3,z) = \max_{a_1,a_2} \pi(p_1,p_2,p_3,w,a_1,a_2,a_3,z) \qquad s.t. \sum_{i=1}^{2} a_i = a \tag{4.6}$$

where a is the total land used for the CO crops and other outputs. The first-order condition for this optimisation problem is similar to (4.4).

$$\frac{\partial \pi(p_1,p_2,p_3,w,a_1,a_2,a_3,z)}{\partial a_1} = \frac{\partial \pi_2(p_1,p_2,p_3,w,a_1,a_2,a_3,z)}{\partial a_2} \qquad s.t. \sum_{i=1}^{2} a_i = a \tag{4.7}$$

and means that shadow prices of the area used for other outputs and CO crops are equalised. From this optimisation the demand function for the area of CO crops can be derived as:

$$a_1 = a_1(p_1,p_2,p_3,w,a,a_3,z) \tag{4.8}$$

The input demand and output supply functions can be derived by differentiating the profit function (4.6) with respect to input and output prices respectively (Hotelling's Lemma).

4.3 Data

Data on specialised arable farms[2], covering the period 1970-1992, were obtained from a stratified sample of Dutch farms which kept accounts on behalf of the LEI-DLO farm accounting system[3]. Farms stay in the panel for only five to six years, so the panel is incomplete. The data set used for estimation contained 5260 observations on 1047 farms.

Three outputs (CO crops, rootcrops and other outputs) and three variable inputs (pesticides, N-fertiliser and other inputs) are distinguished. CO crops consist of winter-wheat, barley, oats and oilseeds. The cereals included account for approximately 85% of the total area of cereals on the farms in the sample. Rootcrops include sugar beet, ware potatoes, seed potatoes and starch potatoes. Other outputs are combined in an aggregate index covering all other marketable crops not accounted for in the previous category, and animal output. Other inputs consist of services, non-nitrogenous fertiliser, seed and planting materials, purchased feed input, energy and other variable inputs.

Fixed inputs are rootcrop-specific area, the total area of CO crops and other outputs, labour and capital. Areas are measured in hectares allocated to each output. Labour is measured in quality-corrected man years, and includes family as well as hired labour. Capital includes capital invested in machinery and livestock, and is measured at constant 1980 prices. Capital invested in buildings was not included since it proved impossible to obtain a reliable value of buildings for all farms in the sample (Elhorst, 1990: p.84).

Tornqvist price indexes were calculated for the three outputs and other inputs (prices were obtained from the LEI-DLO, CBS). The price indexes vary over the years but not over the farms, implying that differences in the composition of a netput or quality differences are reflected in the quantity (Cox and Wohlgenant, 1986). Implicit quantity indexes were obtained as the ratio of value to the price index.

Output prices are not known at the time decisions are made on planting and the use of variable inputs, so expected rather than actual prices have to be used. Expected output prices were constructed by applying an AR(1) filter to the price of CO crops and other outputs and an AR(2) filter to the price of rootcrops. The implication of using expected

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[2] Farms with more than 80% of output coming from marketable crops.

[3] A complete description of the sample can be found in LEI-DLO, 1992.

rather than actual prices is that expected profit is assumed to be maximised instead of actual profit. Expected profit was defined as expected revenue (expected prices times quantities of outputs) minus the total value of the variable inputs actually used.

Other variables that were included in the empirical model are a time trend, and a regional dummy that accounts for the two production regions (=1 for the high productivity region, 0 for the low productivity region).

4.4 Empirical model

4.4.1 Before the 1992 CAP reform

The Normalised Quadratic is the functional form adopted in this study, because overall it came out more favourable on the data set that is used in this study than other linear flexible functional forms. Furthermore, it is empirically simple and has a Hessian of constants allowing convexity in prices to be checked and/or imposed globally. The Normalised Quadratic profit function (see (4.6)), with prices and profit normalised by the price of the other inputs is expressed as:

$$\pi = \alpha_0 + \sum_{i=1}^{5} \alpha_i v_i + \sum_{i=1}^{7} \beta_i z_i + \frac{1}{2}\sum_{i=1}^{5}\sum_{j=1}^{5} \alpha_{ij} v_i v_j + \frac{1}{2}\sum_{i=1}^{7}\sum_{j=1}^{7} \beta_{ij} z_i z_j + \sum_{i=1}^{5}\sum_{j=1}^{7} \rho_{ij} v_i z_j \tag{4.9}$$

where v_i is a vector of normalised netput prices with i=1 (CO crops), 2 (other outputs), 3 (rootcrops), 4 (pesticides) and 5 (N-fertiliser). Furthermore, z_i are areas, fixed inputs, and other variables with i=1 (area CO crops), 2 (area other outputs), 3 (area rootcrops), 4 (labour), 5 (capital), 6 (time trend) and 7 (regional dummy). Symmetry is imposed by requiring that $\alpha_{ij}=\alpha_{ji}$ and $\beta_{ij}=\beta_{ji}$ for all i and j.

The netput (positive for outputs, negative for inputs) equations are derived by differentiating (4.9) with respect to the normalised price of netputs (Hotelling's Lemma):

$$q_i = \alpha_i + \sum_{j=1}^{5} \alpha_{ij} v_j + \sum_{j=1}^{7} \rho_{ij} z_j \qquad i=1,..,5 \tag{4.10}$$

The equation for the numéraire netput can be derived by using the definition of normalised profit: $\pi = v_1.q_1 + v_2.q_2 + v_3.q_3 + v_4.q_4 + v_5.q_5 + q_6$.

$$q_6 = \alpha_0 + \sum_{j=1}^{7} \beta_j z_j - \frac{1}{2}\sum_{i=1}^{5}\sum_{j=1}^{5} \alpha_{ij} v_i v_j + \frac{1}{2}\sum_{i=1}^{7}\sum_{j=1}^{7} \beta_{ij} z_i z_j \tag{4.11}$$

From the optimisation across areas in section 4.2 it follows that shadow prices of the areas of CO crops (z_1) and other outputs (z_2) are equalised, holding the total area of these two crops (a) fixed. This results in one independent area demand equation, which has the following form for CO crops (see (4.8)) before the implementation of the new CO regime:

$$z_1 = \frac{1}{(\beta_{11}+\beta_{22}-2\beta_{12})} \cdot \left[\beta_2-\beta_1+(\beta_{22}-\beta_{12})a+\sum_{j=3}^{7}(\beta_{2j}-\beta_{1j})z_j+\sum_{i=1}^{5}(\rho_{i2}-\rho_{i1})v_i \right] \qquad (4.12)$$

The (total) profit function is estimated together with the netput and the area demand equations in order to increase efficiency. Since the area of CO crops correlates with the error term, an instrumental variable estimator should be applied. Endogenous variables are π, q_i, z_1 and all cross products of z_1 with v_j (j=1,..,5) and z_i(i=1,..,7)[4]. Instruments are all exogenous variables (v_j (j=1,..,5) and z_i (i=3,..,7)), quadratic and cubic terms of exogenous variables and a weather index (see Oskam, 1991). Error terms may be correlated across equations so non-linear 3SLS is an appropriate technique (Judge, et al., 1988: 655). Convexity in prices was imposed by the Wiley, Schmidt and Bramble (1973) technique (see e.g. Dupont, 1991, for an application of this technique).

Every farm is assumed to have different intercepts in the profit function, netput equations and area demand equation reflecting differences in farm characteristics[5]. This assumption is explicitly accounted for by a fixed effects model, the necessary transformation[6] can also be applied to an incomplete panel like our data set (Thijssen, 1992). The parameter estimates[7] and standard errors[8] of the estimated system of equations ((4.9)-(4.10) and (4.12)) can be obtained from the authors. More than 71% of the parameters are significant at the critical 5% level. Another indication of the performance of the model is given by the deviation of calculated (Appendix III : III.1) from actual (Appendix III : Table III.2) values of endogenous variables in 1992. Output quantities are in general

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4 $z_1 + z_2 = a$ is imposed during estimation, so z_1 also appears in variables corresponding to β_2, β_{2j} and ρ_{i2}.

5 Because the netput equations are the first-order derivatives of the profit function with respect to the netput prices, the farm-specific effects should appear as slope coefficients in the profit function. Following Thijssen (1992) we have not done this, thus creating an inconsistency. Including these additional terms would make the system of profit, netput and area demand equations impossible to estimate because of matrix inversion problems.

6 The fixed effects for all equations can be determined in a second stage estimation (Judge, et al., 1988, p.468).

7 Parameters α_{ij} are non-linear combinations of parameters actually estimated (see Dupont, 1991)

8 All standard errors have been corrected for degrees of freedom, which is not accounted for during estimation. Standard errors of the parameters α_{ij} have been calculated according to Rao (1973)

less well predicted than variable input quantities. Weather conditions can be quite different in consecutive years and are the most obvious reason for these deviations.

Tables III.3 and III.4 in Appendix III show the price elasticities and elasticities of intensity for 1992. Although point estimates, these elasticities give an indication of the sensitivity of the endogenous variables with respect to changes in prices and fixed inputs. It is clear that supply of CO crops is more elastic than that of rootcrops, since the latter is restricted by the fixed area.

Shadow prices of fixed inputs can be found in Table III.5 of Appendix III. The average price of renting one hectare of arable land in 1992 was 457 1980 guilders. However, there is rent control in the Netherlands, so we expected the shadow price to be higher than this. The shadow price of capital should be sufficient to pay depreciation, interest, machinery maintenance and insurance. Thus we would expect a value of approximately 0.20, so our finding of 0.028 is rather poor compared to this. Average yearly earnings for an employee who works 40 hours per week, amounted to 52000 1980 guilders in 1992 which is higher than our finding of 28970. These shadow prices indicate that capital and labour were abundant in arable farming in 1992, while land was relatively scarce.

4.4.2 After the 1992 CAP reform

The model derived in the previous section ignores the choice that large producers have with respect to set land aside. Producers in both the high and low productivity regions, region 1 and 0 respectively, have three possibilities within the framework of the new CO regime:

1. They grow less than 12.9 hectares (region 1) or 18.2 hectares (region 0) of CO crops; these producers have no set-aside obligations.
2. They grow more than 12.9 and 18.2 hectares in regions 1 and 0 respectively, but apply for the area premium for exactly this limit in order to avoid compulsory set-aside.
3. They grow more than 12.9 and 18.2 hectares respectively and accept the set-aside obligation in order to receive the area premium for their area of CO crops and the set-aside premium for the area set-aside.

These possibilities have different implications for the profit function and area demand functions under the new regime.

Situation 1

For small producers in both regions, the profit function (4.9) must now include the term $H.z_1$, where H is the premium per hectare and z_1 the area of CO crops. The area demand function then becomes:

$$z_1 = \frac{1}{(\beta_{11}+\beta_{22}-2\beta_{12})} \cdot \left[\beta_2-\beta_1+(\beta_{22}-\beta_{12})a+\sum_{j=3}^{7}(\beta_{2j}-\beta_{1j})z_j+\sum_{i=1}^{5}(\rho_{i2}-\rho_{i1})v_i-H\right] \qquad (4.13)$$

Situation 2

Large producers receive the area premium for the maximum number of hectares of CO crops that carries no set-aside obligation (12.9 or 18.2 hectares). The profit function for this category now includes an additional term 12.9H or 18.2H. The area demand function however remains as in (4.12), because no area premium is received for marginal increases in the area of CO crops.

Situation 3

Large producers have to set 12% of the area of CO crops aside. The profit function for these producers becomes more complex. There is a set-aside premium and an area premium (S and H), so the term $(0.88H+0.12S).z_1$ will appear in their profit function. However, these producers have to set 12% of the area of CO crops (z_1) aside in order to obtain the area premium, so all terms z_1 in (4.9) must be multiplied by 0.88. For example the terms $\beta_{1j}z_1z_j$ become $0.88^2\beta_{1j}z_1z_1$ for j=1 and 0.88 $\beta_{1j}z_1z_j$ for j=2..7. The area demand function then becomes:

$$z_1 = \frac{1}{(0.88^2\beta_{11}+\beta_{22}-1.76\beta_{12})} \cdot \left[\beta_2-0.88\beta_1+(\beta_{22}-0.88\beta_{12})a+\sum_{j=3}^{7}(\beta_{2j}-0.88\beta_{1j})z_j \right. \qquad (4.14)$$
$$\left. +\sum_{i=1}^{5}(\rho_{i2}-0.88\rho_{i1})v_i-0.88H-0.12S\right]$$

When using the model for simulation, the profit and area demand for CO crops are calculated in all three situations. It is then assumed that the producer chooses the option with the highest profit.

4.5 Model simulations

In this section the model simulations together with the simulation results are discussed. The results are aggregated for 12 different farm classes.

4.5.1 Policy simulations

The model that is presented in the previous sections is used to calculate the effects of the new CO regime. The price reduction for CO crops, normalised by the price of the numéraire input, was taken as 34%[9]. The area premium is 866 guilders and 616 guilders per hectare of CO crops in regions 1 and 0 respectively. The area premiums are weighted averages of the actual 1996 area premiums for grains and oilseeds using the share of oilseeds in total production of grains and oilseeds in 1988 and 1991 (2.7%). The set-aside premium is 1075 guilders and 765 guilders per hectare of CO crops in regions 1 and 0 respectively. The area and set-aside premiums are also deflated by the price of the numéraire input. This simulation is the base simulation.

Three other simulations were performed to test the sensitivity of the base simulation with respect to policy parameters: (1) abolition of the set-aside obligation and premiums (area premiums unchanged), (2) a 25% reduction in area premiums (set-aside premiums unchanged) and (3) a price reduction for CO crops that leaves total profit unchanged (area and set-aside premiums unchanged).

These measures are simulated for every farm in the sample in 1992. Because of the large number of farms in the sample used for simulation (232) and in order to simplify the interpretation of the model outcomes, results were aggregated for different classes of farms and sector as a whole using the number of farms in the sector that each farm in the sample represents as weights. The classification of farms in table 4.1 is based on the fact that farms in region 1 have no set-aside obligations if they grow less than 12.9 hectares of CO crops; in region 0 this is 18.2 hectares. Whereas the size of the farm, measured as the area of CO crops, indicates the absolute importance of CO crops for a farm, the intensity of the farm, measured as the share of rootcrops in the crop rotation, indicates the relative importance of CO crops. The share of 50% is close to the average share of rootcrops for the farms in the sample (49%). Farms were classified using the calculated values for the area of CO crops and the actual share of rootcrops in 1992. The policy simulations cause farms to shift from one class to another because the area of CO crops can vary.

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[9] This is the decrease in the intervention price for soft wheat in 1996 compared to 1992 corrected for the numéraire price in 1992.

Table 4.1. Arable farm classification (1 to 12) and the number of farms in each class (in parentheses).

Intensity / Area of CO crops	≤ 12.9 ha	12.9-18.2 ha	≥ 18.2 ha
Region 0 (low productivity)			
< 50% ha potatoes and sugar beet	1 (569)	2 (58)	3 (49)
≥ 50% ha potatoes and sugar beet	4 (1334)	5 (59)	6 (111)
Region 1 (high productivity)			
< 50% ha potatoes and sugar beet	7 (1793)	8 (1123)	9 (1390)
≥ 50% ha potatoes and sugar beet	10 (1529)	11 (318)	12 (266)

4.5.2 Results

The results of the base simulation are presented in table 4.2. All farm classes reduce their output and area of CO crops; this holds in particular for small producers in the low productivity region (farm classes 1 and 4). The reduction of the output and area of CO crops leads to sometimes substantial changes in the production of other outputs. A reduction of other outputs and CO crops is found for large farms (farm classes 3, 8, 9, 11 and 12) that participate in the set-aside arrangements. The production of other outputs increases on those farms that increase the area of other outputs; it decreases on farms that participate in the set-aside, and therefore, decrease the area of other outputs. The highest percentages of land set-aside are found for large extensive farms in both regions (farm classes 3 and 9).

A profit reduction is found for all farms. This implies that the compensatory payments are too low to compensate farmers for their loss in profit due to the lower price for CO crops. Furthermore farms that participate in the set-aside arrangements (especially in the high productivity region) are faced with a larger reduction in profit than other farms. These farms are relatively more dependent upon CO crops. For the sector as a whole, profit decreases by 2%.

Table 4.2. Effects[1] of the new CO regime : The base simulation (upper part) and the base simulation without set-aside (lower part).

	netput quantities						miscellaneous			
farm class	CO crops	other outputs	rootcrops	pesticides	N-fertiliser	other inputs	Area CO crops[2]	Area of other outputs	% of total area set-aside	profit[3]
Base simulation										
1	-55.99	0.96	0.09	-4.49	-9.72	1.88	-57.07	9.05	0.00	-0.37
2	-12.19	6.71	0.10	-5.38	-7.09	-10.61	-11.53	18.61	0.00	-3.06
3	-10.76	-5.07	1.30	-4.60	-9.46	-4.73	-9.98	-4.50	4.79	-3.05
4	-44.06	3.63	0.05	-2.67	-5.80	-1.76	-41.06	14.16	0.00	-0.55
5	-14.22	10.67	0.04	-2.43	-3.34	-4.21	-10.35	38.11	0.00	-0.70
6	-12.14	1.61	0.26	-1.60	-3.15	-3.74	-9.70	7.51	1.02	-0.96
7	-6.01	0.74	-0.19	-2.86	-6.66	2.34	-6.40	4.38	0.00	-2.04
8	-6.87	-1.51	0.67	-3.57	-7.27	2.03	-7.67	-0.69	2.66	-2.87
9	-6.10	-5.36	1.45	-3.42	-6.99	1.92	-7.39	-9.47	5.21	-4.05
10	-8.06	0.81	-0.09	-1.96	-7.23	1.87	-8.38	5.59	0.00	-0.77
11	-6.01	-2.24	0.37	-1.89	-5.22	0.27	-7.03	-5.12	2.70	-1.65
12	-6.90	-4.45	0.60	-2.18	-6.37	1.43	-8.53	-9.88	3.95	-2.53
sector	-8.91	-0.44	0.39	-2.83	-6.65	0.81	-9.97	2.08	2.06	-1.99
Base simulation without set-aside[4]										
3	-4.67	2.55	0.03	-2.05	-3.55	-7.67	-4.07	8.00	0	-1.59
6	-10.26	4.55	0.03	-1.34	-2.46	-3.44	-8.03	11.89	0	-0.99
8	-3.35	0.82	-0.16	-2.32	-4.17	1.65	-3.41	3.30	0	-2.95
9	-1.56	0.64	-0.10	-1.33	-2.19	0.17	-1.65	2.98	0	-3.16
11	-2.95	0.77	-0.07	-1.19	-2.84	0.84	-3.11	6.42	0	-1.91
12	-1.72	0.73	-0.05	-0.87	-2.09	0.16	-1.87	5.25	0	-2.00
sector	-5.89	1.18	-0.07	-2.10	-4.48	0.39	-6.26	6.20	0	-1.75

1: percentage changes in quantities of netputs, area of CO crops and other outputs, land set-aside and profit compared to the calculated 1992 level
2: Excluding area set-aside
3: Normalised value of all netputs[10] 4: Results for other farm classes remain unchanged

[10]This calculated profit differs in general from profit calculated with the profit function (4.9), because every netput equation has a fixed effect that does not appear in the profit function.

The new measures result in a 2.8% overall reduction in pesticide use. This reduction is highest for farms that substantially reduce the area of CO crops and/or participate in the set-aside arrangement. This is because CO crops use pesticides more intensively than other outputs. CO crops also use N-fertiliser more intensively than other outputs. Therefore, due to the reduction of the area of CO crops and the lower price of CO crops, a reduction in N-fertiliser use is found for all farm types.

A measure of the dynamics of the sector as a result of the new CO regime can be found in the change of the number of farms per class. Farms cannot move from one region to an other, or change the intensity of the farm, since the total area and the area of rootcrops are fixed, but they can adjust their area of CO crops. Simulations show that if farms move to another farm class this is in general because the CO area decreases (farms move from farm class 2 to 1, from 6 to 5, from 8 to 7, from 11 to 10 and from 12 to 11). Table III.6 shows that most large farms, in the new situation, participate in the set-aside arrangements.

The effects of the abolition of the set-aside arrangements, a 25% reduction of the area premiums and a price reduction leaving profit unchanged are given in Tables 4.2 and III.7. Here the results are summarised. Abolishing the set-aside arrangement has little effect relative to the base simulation. Not surprisingly, at the sector level the reduction in CO output is smaller (-5.9%), and the decrease in profit is smaller (-1.8%). The reduction in pesticide use is now 2.1%, so participation in the set-aside arrangements for large farmers accounts for an additional 0.7% reduction in pesticide use. Changes in model results compared to the base simulation at the sector level are caused by farms that participated in the set-aside arrangements in the base simulation.

A 25% reduction of the area premiums, leaving the set-aside arrangements intact, makes CO crops unattractive: production and area decrease by 14.6% and 16.5% respectively (see table III.7). The production of other outputs increases by 1.2% and that of rootcrops by 0.5%. Profit falls by 3.2%. The area set-aside (1.9%) is slightly smaller than in the base simulation (2.1%) because growing CO crops has become less attractive. Pesticide and N-fertiliser use fall by 3.7% and 8.5% respectively.

A 24% price reduction for CO crops, together with the area and set-aside premiums of the base simulation, would give a zero overall profit change (see table III.7). In this case production of CO crops falls less (-0.7%) and more land is set aside (2.3%). The production and area of other outputs fall by 2.7% and 7.8% respectively, and the decreases in pesticide and N-fertiliser use are smaller (1.3% and 3.2% respectively).

The results of all three simulations show large difference between groups of farms.

4.6 Discussion and conclusions

At the sector level, simulations of the new CO regime show a reduction of the output of CO crops and other outputs of 8.9% and 0.4%, respectively, and an increase in rootcrop output of 0.4%. Pesticide and N-fertiliser use decrease by 2.8% and 6.7%, respectively. Profit falls by 2%. Further, it is shown that large farms react to the new measures by reducing the area of CO crops and opting for set-aside. Data on participation in the set-aside for 1993 (LEI-DLO, 1995) indicate that 2.1% of the land in arable farming was set-aside, which is close to our findings (although the set-aside percentage was 15 in 1993). Moreover, preliminary data (LEI-DLO/CBS, 1994) show that it is large extensive farms in both regions that set land aside.

From table 4.2 and III.7 it can be seen that area premiums are not fully decoupled from price levels because the quantities of all netputs change due to a change of the area premiums. Moreover, it can be seen that the new CO regime contributes to a reduction of N-fertiliser and pesticides use.

When interpreting the results, it is important to be aware of the following points. First, during estimation and simulation, the occurrence of corner solutions, i.e. zero observations for outputs and areas, was not taken into account. This implies that the calculated values of these variables could be negative. For example, the calculated area of both CO crops and other outputs in 1992 was negative in 6 instances. Second, in the model all prices, technological change, the area of rootcrops and the total area of CO crops and other outputs are exogenous, which is an unrealistic assumption in the long run. Third, the model does not take into account that farms are allowed to manage the set-aside land so as to improve future soil fertility or to grow agro-industrial crops. The latter use of set-aside land is however not very important in the Netherlands (LEI-DLO/CBS, 1995). Fourth, the price reduction for CO crops that we used in the simulations is rather uncertain. The European Union has reduced the intervention price, but the market price will also depend on market conditions. Moreover, as a result of the regime switch, the price of CO crops will be less stable than before, in which case the reaction of risk-averse producers will be different from that of risk-neutral producers.

In conclusion, the model provides predictions of the regional, farm-specific and sectoral effects of the new CO regime. The model can easily determine the simultaneous effects of different policy changes (e.g. abolishing set-aside obligations and reducing area premiums).

Chapter 5

Effects of N-surplus Taxes : Combining Technical and Historical Information

Summary

Technical information on the production of an externality can be included in a dual profit function to yield insight into the effects of a tax on the externality. The methodology is applied to a tax on Nitrogen-surplus in the context of future mineral policies for Dutch arable farms. In future policy, N-surplus will probably be calculated using an accounting relationship that relates inputs and outputs to N-surplus.

The simulation model used to determine the effects of the tax on N-surplus is based on equations that have been estimated with panel data.

A 0.27 guilder tax per kg N-surplus with a threshold of acceptable N-losses of 75 kg/ha and a 18% levy on N-fertiliser were found to give the same reduction of N-surplus as a 1 guilder tax on N-surplus with a 125 kg/ha threshold. The N-surplus taxes induce producers with a high N-surplus to lower the N-surplus more than producers with a small N-surplus and should therefore be preferred from an environmental perspective.

Keywords : N-surplus, panel data, simulation model

5.1 Introduction

Optimal environmental policy requires taxing an externality rather than the inputs or outputs generating the externality (Baumol and Oates, 1988: 46). Ideally, in order to analyse the effects of a tax on the externality, using econometric models, one should have historical information on prices and quantities of netputs together with levies on, and the quantity of, the externality. Usually, however, this information is not available at the time of the introduction of the policy.

The lack of independent information in the data set on the quantity of the externality produced as prices vary necessitates calculating its value from actual use of inputs and/or production of outputs. In previous research, the quantity of the externality that is thus obtained was included as a fixed netput when estimating the profit function, so as to infer information on its marginal value product (e.g. Fontein et al., 1994). This approach is, however, not satisfactory for a number of reasons. First, fixed other inputs strongly correlated with the externality have to be excluded during estimation in order to avoid multicollinearity. Doing so, however, obscures the true underlying production relationships and biases the estimated marginal value product of the externality. Second, if an externality is closely related with a short-term variable netput, then including the externality in the profit function as a fixed netput in the profit function is theoretically inconsistent, because this suggests that the quantity of the externality is invariable in the short term.

This chapter shows that including the level of the externality, either as an observed or an imputed value in the profit function to be estimated can be avoided. Inference regarding the effects of a tax on an externality can be obtained by simulation, using a dual profit function representing producers' decisions prior to the introduction of the tax, into which a production function for the externality is introduced.

The methodology is illustrated in the context of a policy to tax the nitrogen surplus generated by arable farms in the Netherlands. Nitrogen surplus is used as a proxy for pollution, and the formula for calculating the N-surplus plays the role of the "production function" for the externality. Current policy on minerals for the arable sector involves a limit on the use per hectare of phosphates of animal origin. Future policies on minerals will probably oblige all farms to keep a mineral account for flows of nitrogen and phosphates from manure as well as artificial fertiliser (Tweede Kamer, 1995 and 1996). In this way detailed information on the uptake of minerals by crop products and the supply of minerals through artificial fertiliser and manure will be available. The difference between supply and uptake, minus a threshold level for acceptable mineral losses per hectare, constitutes mineral surpluses per farm that will be taxed. This chapter examines the effects of this policy, applied to nitrogen surpluses[1,2], for arable farms. The effects will be compared with a tax on N-fertiliser.

The reactions of arable farms in the Netherlands are examined using an extended version of the simulation model of Dutch arable farming that was developed in Chapter 4.

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1 This policy is planned to be applied to intensive livestock farms in 1998. Extensive livestock, horticultural and arable farms are provisionally exempted.

2 We omitted nitrogen from manure during estimation and simulation, although the use of animal manure increased importantly during the eighties. However, arable farmers apply manure mainly as a means of increasing the organic matter content of the soil (Baltussen et al., 1992: 52). The application of manure in the fall causes the effectiveness of N from manure to be low. Moreover, there is evidence that farmers do not take the supply of N into account when choosing levels of N from N-fertiliser (Baltussen et al., 1992: 52). Therefore we believe that excluding animal manure during estimation does not bias the coefficients related to the price of N-fertiliser. The effect of excluding the use of animal manure from the simulations is small since the scenarios that are under review in this paper are so constraining, that they do not allow for applying any animal manure at all (LEI-DLO, 1995).

The simulation model calculates the short-term effects of the nitrogen policies for the farms in the panel. Simulation results are aggregated for different classes of farms and for the sector as a whole.

In this chapter, the theoretical model is elaborated in section 5.2 and the empirical model is presented in section 5.3. Section 5.4 offers a discussion of the simulations and simulation results and the chapter concludes with comments.

5.2 Including the externality in the theoretical model

This section assumes that knowledge about the production function of an externality is available and shows how this knowledge can be included in the theoretical model of Chapter 4 to yield information about the effect of a levy on an externality.

The basic theoretical model of Chapter 4 is given by :

$$\pi(p,w,a,a_3,z) = \max_{a_1,a_2} \pi(p,w,a_1,a_2,a_3,z) \qquad s.t. \sum_{i=1}^{2} a_i = a \tag{5.1}$$

where π is profit, defined as $p.q - w.x$; p a vector of output prices; w a vector of input prices; x and z are vectors of variable and fixed inputs respectively, q a vector of outputs and a_i is the output-specific area, with i=1 (CO crops), 2 (other outputs) and 3 (root-crops). π is assumed to be twice continuously differentiable, linearly homogeneous and convex in prices, increasing in fixed quantities and output prices and decreasing in input prices (Chambers, 1988: 124-126). The maximisation problem (5.1) implies that areas can shift between CO crops and other outputs.

In order to include the information on the production function of the externality, the vector x of variable input quantities in maximisation problem (5.1) is partitioned into two subsets of inputs x_1 and x_2 with corresponding prices w_1 and w_2. The externality is produced with a known production function $F(.)$ by subset x_2 only. This production function is given by :

$$q_0 = F(x_2) \tag{5.2}$$

where q_0 is the quantity of the externality. The properties of $F(.)$ are discussed below.

Maximisation problem (5.1) is rewritten as :

$$\pi(p,w_1,w_2,a,a_3,z) = \max_{a_1,a_2}\{ \pi(p,w_1,w_2,a_1,a_2,a_3,z)\} \qquad s.t.\sum_{i=1}^{2} a_i = a \tag{5.3}$$

where

$$\pi(p,w_1,w_2,a_1,a_2,a_3,z) = \max_{x_2}\{G(p,w_1,x_2,a_1,a_2,a_3,z) - w_2 \cdot x_2 \mid (q,x_1,x_2,a_1,a_2,a_3,z) \in T\} \tag{5.4}$$

T is the technology set containing all feasible input-output combinations and G(.) is a restricted profit function, defined as $p.q - w_1.x_1$. The parameters from $G(.)$ can be derived from those of $\pi(.)$ and vice versa by using standard methods (Fulginiti and Perrin, 1993; Guyomard and Mahé, 1993) (see also Appendix IX).
If firms pay a tax p_0 for producing the externality, the profit maximisation problem (5.4) becomes:

$$\Pi(p,p_0,w_1,w_2,a_1,a_2,a_3,z) = \max_{x_2}\{ G(.) - w_2x_2 - p_0F(x_2) \mid (q,q_0,x_1,x_2,a_1,a_2,a_3,z) \in T\} \tag{5.5}$$

and has first order condition:

$$\frac{\partial G(.)}{\partial x_2} - w_2 - p_0\frac{\partial F(x_2)}{\partial x_2} = 0 \tag{5.6}$$

The second order condition for profit maximisation requires that the matrix :

$$\frac{\partial^2 G(\cdot)}{\partial x_2 \partial x_2} - p_0\frac{\partial^2 F(x_2)}{\partial x_2 \partial x_2} \tag{5.7}$$

is negative semi-definite. Note that the second order condition for profit maximisation in (5.4) requires

$$\frac{\partial^2 G(\cdot)}{\partial x_2 \partial x_2}$$

to be negative semi-definite. Therefore, a sufficient but not necessary condition for (5.7) to be negative semi-definite is that

$$\frac{\partial^2 F(\cdot)}{\partial x_2 \partial x_2}$$

is positive semi-definite, i.e. $F(x_2)$ is convex in x_2. Convexity of $F(x_2)$ in x_2 implies that the production function of the externality exhibits a non-decreasing marginal product with respect to input levels. As Helfand and House (1995) note, this is a characteristic that is typically exhibited by pollution functions.

Equation (5.6) states that, due to the tax on the externality, the value of the marginal product of x_2 $(\partial G(.)/\partial x_2)$ increases[3] by $p_0.\partial F(x_2)/\partial x_2$. Therefore the optimal quantity after the tax (x_2^*) is lower than the optimal quantity before the tax: x_2. Solving the first order condition (5.6) yields the demand function for x_2^* after the policy has been implemented:

$$x_2^* = x_2^*(p,p_0,w_1,w_2,a_1,a_2,a_3,z) \tag{5.8}$$

The supply equation for the externality can be obtained by inserting (5.8) into (5.2), whereas the netput equations can be derived by applying Hotelling's Lemma to $G(.)$ and subsequently inserting (5.8). The CO crops area demand equation is obtained by performing an optimisation across a_1 and a_2 (see also chapter 4 : section 4.2) :

$$\frac{\partial \Pi^*(p,p_0,w_1,w_2,a_1,a_2,a_3,z)}{\partial a_1} = \frac{\partial \Pi^*(p,p_0,w_1,w_2,a_1,a_2,a_3,z)}{\partial a_2} \quad s.t.\ a_1 + a_2 = a \tag{5.9}$$

where $\Pi^*(p,p_0,w_1,w_2,a_1,a_2,a_3,z) = p \cdot q - w_1 \cdot x_1 - w_2 \cdot x_2^* - p_0 \cdot q_0$

5.3 Empirical model

In this section, the empirical model of Chapter 4 is extended with an accounting relationship for N-surplus that is used by the government as a base for taxing Dutch arable farms. It should be noted that N-surplus is determined using an accounting relationship rather then a 'true' production function. This is because an accounting

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[3] The marginal product increases since, according to first order condition (6), the vector $\partial G(.)/\partial x_2 - p_0 \partial F(x_2)/\partial x_2$ has to equal w_2. Since w_2 does not change and because $p_0 \partial F/\partial x_2$ is non-negative, the elements of the vector of marginal value products ($\partial G/\partial x_2$) have to increase. A larger marginal value product corresponds with lower optimal quantities in x_2 under the tax policy.

relationship as a base for taxing farmers will be used in the policy on minerals for the intensive livestock sector, and therefore, probably will be used in future policy for the arable sector. The government could also decide to use very detailed agronomic information on the relationship between farming practice and N-surplus, but such a policy would be more costly and perhaps also impossible to monitor. This is because the 'true' N-surplus depends on variables as yield per hectare, weather, soil type, etcetera.

In order to determine the effects of a tax on N-surplus, the post-CAP reform equations have to be adjusted as described in section 5.2. First, the equation for the N-surplus on farm h is specified, followed by the equations for netputs and the area of CO crops. These equations are given for situations 1-3 that apply for all arable farms after the 1992 CAP reform (see Chapter 4 : section 4.4.2), to begin with situation 1.

The specification of the N-surplus function assumes that under the tax policy farmers are obliged to keep accounts of N flows on the farm. Information that is available through the accounts includes uptake by crops and purchases of N-fertiliser. Total N-surplus at the farm level (q_{0h}) is calculated using an accounting relationship :

$$q_{0h} = S_{Nh} - D_{Nh} + E_{Nh} - T_{Nh} \tag{5.10}$$

where (S_{Nh}) is Nitrogen supplied by N-fertiliser, D_{Nh} is uptake by crop products, E_{Nh} is exogenous deposition (mainly through ammonia) and T_{Nh} is a threshold level for acceptable N losses.

Nitrogen supplied by N-fertiliser (S_{Nh}) is calculated by transforming the implicit quantity of N-fertiliser (which is in 1980 guilders) to kg N, using the average normalised price per kg N in 1992: p_N. Algebraically:

$$S_{Nh} = -\gamma_S q_{5h} \tag{5.11}$$

where $\gamma_S = 1/(p_N)$.

Net uptake (uptake by crop products minus supply through seeds and planting materials)[4] of N by output is calculated using yield and soil type independent norms per crop and per farm (Janssens and Groenwold, 1993). This simplification will probably be used in the policy with regard to the arable sector because it is already used for the intensive livestock sector.

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[4] Data on net uptake by crop are available at the level of individual crops that the aggregate outputs are composed of (Janssens and Groenwold, 1993 : 64). Net uptakes given by γ_1,γ_2 and γ_3 are farm specific, since the composition of outputs differs by farm.

$$D_{Nh} = \gamma_{1h} \cdot z_{1h} + \gamma_{2h} \cdot z_{2h} + \gamma_{3h} \cdot z_{3h} \tag{5.12}$$

In (5.12), γ_{ih} are net uptakes for crop i on farm h and z_i (i=1..3) are defined as before. It can be seen that net uptake contains the endogenous variable z_1.
Exogenous deposition is the product of deposition per hectare and the total area.

$$E_{Nh} = \gamma_E \cdot (z_{1h} + z_{2h} + z_{3h}) \tag{5.13}$$

Finally, the threshold level for N-surplus at the farm level (T_{Nh}) is the product of the threshold level per hectare and the total area.

$$T_{Nh} = \gamma_T \cdot (z_{1h} + z_{2h} + z_{3h}) \tag{5.14}$$

The value that γ_T takes will be discussed in section 5.4.1. Table 5.1 presents the (average) values of all other γs in 1992.

Table 5.1 : Average values of γ_S, γ_{ih} and γ_E in 1992

variable	dimension	value	standard deviation
γ_{1h}^{a}	kilogram/hectare	97.63[b]	20.03[b]
γ_{2h}^{a}	kilogram/hectare	71.46[b]	2.73[b]
γ_{3h}^{a}	kilogram/hectare	66.95[b]	11.82[b]
γ_S	kilogram/1000 guilders	1113.04[c]	-
γ_E	kilogram/hectare	53[b]	-

a) Mean value and standard deviation.
b) Source : Janssens and Groenwold, 1993: 30-64, and own computations
c) Source : LEI-DLO, 1995a and own computations

Inserting (5.11)-(5.14) into (5.10) yields:

$$\begin{aligned} q_{0h} &= -\gamma_S q_{5h} - (\gamma_{1h} - \gamma_{2h}) z_{1h} - \gamma_{2h} a_h - \gamma_{3h} z_{3h} - (\gamma_T - \gamma_E)(z_{1h} + z_{2h} + z_{3h}) \\ &= -\gamma_S q_{5h} - (\gamma_{1h} - \gamma_{2h}) z_{1h} - C_h \end{aligned} \tag{5.15}$$

where C_h is a farm specific constant; a_h is the area of other outputs and CO crops at farm h. Total N-surplus can be considered as an undesirable output with a corresponding (negative) price representing the tax that is imposed on surplus. It can be seen that the N-surplus function is linear in inputs. If the government used a 'true' production relationship that was strictly convex instead of linear in polluting inputs, then farmers with a high production intensity would be more heavily taxed than in the case of a linear relationship. This is because farmers with a high production intensity use polluting inputs (e.g. N-fertiliser) more intensively than farmer with a low production intensity. Notice that linearity of the accounting relationship implies that $\partial^2 q_{0h} / \partial q_{5h}^2$ is zero, i.e. the second order condition for profit maximisation of (5.5) is fulfilled.

After specifying the N-surplus function, the area demand and netput equations are derived using the methodology that was elaborated in section 5.2. Defining v_0 as the normalised levy on N-surplus, the netput equation is :

$$q_i = \alpha_i + \sum_{j=1}^{5} \alpha_{ij} v_j + \sum_{j=1}^{7} \rho_{ij} z_j + \gamma_S \alpha_{i5} v_0 \quad i=1,..,5 \tag{5.16}$$

the equation for the numéraire netput is:

$$q_6 = \alpha_0 + \sum_{j=1}^{7} \beta_j z_j - \frac{1}{2} \sum_{i=1}^{5} \sum_{j=1}^{5} \alpha_{ij} v_i v_j + \frac{1}{2} \sum_{i=1}^{7} \sum_{j=1}^{7} \beta_{ij} z_i z_j - \sum_{i=1}^{5} \gamma_S \alpha_{i5} v_i v_0 - \frac{1}{2} \gamma_S^2 \alpha_{55} v_0^2 \tag{5.17}$$

and the area demand equation is :

$$z_1 = \frac{1}{(\beta_{11} + \beta_{22} - 2\beta_{12})} \cdot \left[\beta_2 - \beta_1 + (\beta_{22} - \beta_{12}) a + \sum_{j=3}^{7} (\beta_{2j} - \beta_{1j}) z_j \right. $$
$$\left. + \sum_{i=1}^{5} (\rho_{i2} - \rho_{i1}) v_i + (\gamma_S (\rho_{52} - \rho_{51}) + (\gamma_{2h} - \gamma_{1h})) v_0 - H \right] \tag{5.18}$$

For large farms that do not participate in the set-aside (situation 2 in 4.4.2), the netput equations and the equation for the numeraire input are the same as those for small farms ((5.16)-(5.17)). The area demand equation becomes :

$$z_1 = \frac{1}{(\beta_{11} + \beta_{22} - 2\beta_{12})} \cdot \left[\beta_2 - \beta_1 + (\beta_{22} - \beta_{12}) a + \sum_{j=3}^{7} (\beta_{2j} - \beta_{1j}) z_j \right. $$
$$\left. + \sum_{i=1}^{5} (\rho_{i2} - \rho_{i1}) v_i + (\gamma_S (\rho_{52} - \rho_{51}) + (\gamma_{2h} - \gamma_{1h})) v_0 \right] \tag{5.19}$$

The N-surplus for farms that participate in the set-aside (situation 3 in 4.4.2) has to be corrected for the fact that the area set-aside (12% of the total area of CO crops) does not contribute to removal of N by crop products.

$$
\begin{aligned}
q_{0h}^{s-a} &= -\gamma_S q_{5h} - (0.88\gamma_{1h}-\gamma_{2h}-0.12\gamma_T)z_{1h} - (\gamma_T-\gamma_E)(z_{1h}+z_{2h}+z_{3h}) - \gamma_{2h}a_h-\gamma_{3h}z_{3h} \\
&= -\gamma_S q_{5h} - (0.88\gamma_{1h}-\gamma_{2h}-0.12\gamma_T)z_{1h} - C_h
\end{aligned}
\tag{5.20}
$$

The netput equations are:

$$
q_i^{s-a} = \alpha_i + \sum_{j=1}^{5} \alpha_{ij}v_j + 0.88\rho_{i1}z_1 + \sum_{j=2}^{7} \rho_{ij}z_j + \gamma_S\alpha_{i5}v_0 \qquad i=1,..,5 \tag{5.21}
$$

The equation for the numeraire netput is:

$$
\begin{aligned}
q_6 = {}& \alpha_0 + 0.88\beta_1 z_1 + \sum_{j=1}^{7} \beta_j z_j - \frac{1}{2}\sum_{i=1}^{5}\sum_{j=1}^{5} \alpha_{ij}v_i v_j + \frac{1}{2}0.88^2\beta_{11}z_1^2 + 0.88\sum_{j=2}^{7} \beta_{1j}z_1 z_j + \\
& \frac{1}{2}\sum_{i=2}^{7}\sum_{j=2}^{7} \beta_{ij}z_i z_j + \sum_{i=1}^{5} \gamma_S\alpha_{i5}v_i v_0 - \frac{1}{2}\gamma_S^2\alpha_{55}v_0^2
\end{aligned}
\tag{5.22}
$$

And finally, the area demand equation is:

$$
\begin{aligned}
z_1 = {}& \frac{1}{(0.88^2\beta_{11}+\beta_{22}-1.76\beta_{12})} \cdot \Bigg[\beta_2 - 0.88\beta_1 + (\beta_{22}-0.88\beta_{12})a + \sum_{j=3}^{7} (\beta_{2j}-0.88\beta_{1j})z_j \\
& + \sum_{i=1}^{5} (\rho_{i2}-0.88\rho_{i1})v_i + (\gamma_S(\rho_{52}-0.88\rho_{51}) + (0.12\gamma_T+\gamma_{2h}-0.88\gamma_{1h}))v_0 - 0.88H - 0.12S \Bigg]
\end{aligned}
\tag{5.23}
$$

5.4 Model simulations

In this section the model simulations together with the simulation results are discussed. The results are aggregated for 4 different farm classes.

5.4.1 Policy simulations

The model presented in the previous sections is used to calculate the effects of a tax on N-surplus. All effects are compared to a base simulation that represents the new EU regime for cereals and oilseeds in 1993. In this base simulation, the prices of all netputs except for the price of CO crops are assumed to remain at their 1992 level. The price reduction for CO crops, normalised by the price of the numéraire input, is taken as 22%[5]. The area premium is 494 guilders and 352 guilders per hectare of CO crops in regions 1 and 0 respectively. The area premiums are weighted averages of the actual 1993 area premiums for grains and oilseeds using the share of oilseeds in total production of grains and oilseeds in 1988 and 1991 (2.7%). The set-aside premium is 849 guilders and 604 guilders per hectare of CO crops in regions 1 and 0 respectively. The area and set-aside premiums are also deflated by the price of the numéraire input. The calculated values in the base simulation can be found in Appendix IV (Table IV.1).

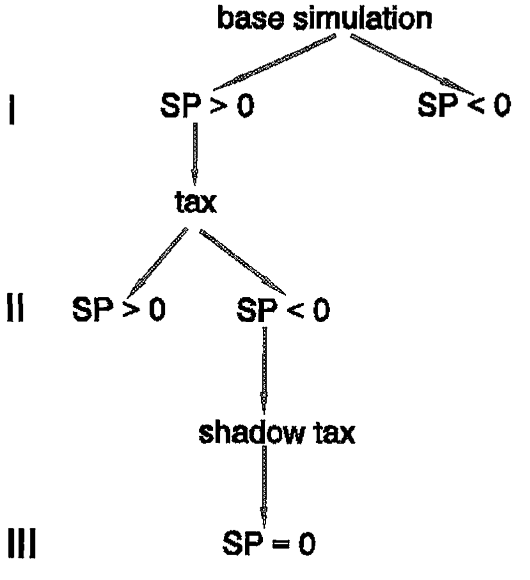
After constructing this base simulation, three different policy simulations are performed. In the first simulation, farms pay a 1 guilder per kg N tax on the calculated N-surplus with a prespecified threshold level of 125 kilograms N per hectare (as suggested by the LEI-DLO, 1995b). In the second simulation, farms pay a tax on the calculated N-surplus with a prespecified threshold level of 75 kilograms N per hectare. The third simulation involves a tax on N-fertiliser. The taxes in the second and third simulations are such that the total reduction of N-surplus per hectare at the sector level is equal to that in the first simulation.

Figure 1 shows the decision sequence that is used in order to calculate the effects of a tax on N-surplus (first and second simulation). In stage I, farms that have an N-surplus after the base simulation ($SP > 0$) are separated from farms that do not have an N-surplus ($SP < 0$). The end solution is obtained at this stage for farms that do not have an N-surplus. Farms that have an N-surplus are confronted in stage II with the tax on N-surplus. The end solution is obtained here for farms that still have an N-surplus under the tax regime. Farms that have no N-surplus after the introduction of the tax ($SP < 0$) have a

---

[5] This is the decrease in the intervention price for soft wheat in 1993 compared to 1992 corrected for the numéraire price in 1992.

figure 1 : simulation steps



corner solution for the N-surplus, these farms will optimise profit at SP=0. This is imposed in the simulation model by calculating a farm-specific shadow tax (stage III) that yields SP=0. The shadow tax is used to calculate the quantities of netputs and the area of CO crops; the actual tax that farms pay is zero.

The simulations are performed for every farm in the sample in 1992. Because of the large number of farms in the sample used for simulation[6] (232) and in order to simplify the interpretation of the model outcomes, results were aggregated for different classes of farms and for the sector as a whole using the number of farms in the sector that

---

[6] The model was estimated over the period 1970-1992 using data on 1047 farms. However, the panel is unbalanced, because farms stay in the panel for 5-6 years. Therefore only 232 farms were in the panel in 1992 and these farms were used for simulations. These farms represent the arable farming sector in the Netherlands in 1992.

each farm in the sample represents as weights. The classification of farms in table 5.2 is based on the region and the size of the N-surplus after the base simulation. The threshold level that is used is 125 kg per hectare. Farms were classified using the calculated values for the N-surplus after the 1992 CAP reform. The policy simulations cause farms to shift from one class to another because the N-surplus can vary.

Table 5.2. Arable farm classification (1 to 4) and the number of farms in each class in the raised sample (in parentheses).

Surplus	low productivity region	high productivity region
N-surplus $\leq$ 125 kg/ha	1 (1276)	2 (5303)
N-surplus $>$ 125 kg/ha	3 (904)	4 (1116)

5.4.2 Results

The results of the simulations can be found in Table 5.3. Farms in classes 1 and 2 have an N-surplus that is smaller than 125 kg per hectare in the base simulation. Thus, there are no changes for these farms under the first scenario, whereas farms in classes 3 and 4 reduce their output and area of CO crops, since N-losses are larger for CO crops than for other outputs. Part of the decrease in the N-surplus comes from a lower intensity of production of both CO crops and other outputs, since the decrease (increase) in the area of CO crops (other outputs) is smaller (larger) than the decrease (increase) in the output of CO crops (other outputs).

The lower intensity of production is also apparent from the substantial reduction of N-fertiliser use on both farms. The N-surplus decreases by 40 and 28 kg/hectare in region 0 and 1 respectively. The regional difference in the reduction of N-surplus is explained by the fact that farms in region 0 use N-fertiliser more intensively than farms in region 1. The effects on other variables are small, but the policy is very successful in bringing the N-surplus at the farm level below the threshold level of 125 kg/hectare : 87% of farms in class 3 and 74% of the farms in class 4 have decreased the surplus to or below 125 kg/hectare. The government might also decide to introduce a prohibitive levy on N-surplus, i.e. a levy that induces all arable farmers to reduce the N-losses below the 125 kg/hectare threshold level. This model calculates that a levy of 4.1 guilders per kg N-surplus is sufficient for that.

The levy on N-surplus with a threshold of 75 kg that brings about the same change of N-surplus at the sector level as a levy of one guilder/kg with a threshold of 125 kg is calculated as 0.27 guilder/kg. All farms react to this levy by reducing the area CO crops and decreasing the intensity of production of CO crops and other outputs. Also in this simulation, the effects are larger for farms in region 0 than for farms in region 1. The reduction of the N-surplus is much larger for farms that have an N-surplus that exceeds 125 kg per hectare in the base simulation (farms in classes 3 and 4). At the sector level, the effects of the one guilder levy on N-surplus with a 125 kg threshold are almost the same as the effects of this simulation. In this simulation, 12% of the farms that initially had an N-surplus larger than 75 kg per hectare in region 0 and 41% of the farms in region 1 have decreased the N-surplus to or below the level of 75 kg per hectare. Given the size of the levy, it may be expected that a one guilder levy with a 75 kg threshold will have more substantial effects. This can also be seen in Table 5.3 where the profit reduction at sector level is found to be 1.05%. This implies that farmers are on average 1165 guilders worse off if the government decides to impose a levy of 1 guilder with a threshold of 75 kg/hectare instead of the 0.27 guilder/kg levy with the same threshold.

An ad valorem levy on N-fertiliser of 18.73% was calculated to give the same reduction of the N-surplus as the one guilder levy on N-surplus with a 125 kg per hectare threshold. Table 5.3 shows that the proportionate reduction of the N-surplus is now almost equal for all farms, implying that farms that initially have a large N-surplus do not reduce the surplus more than farms that initially have a small N-surplus. This is also shown by the fact that 15% of the farms in class 3 and 17% of the farms in class 4 have reduced the N-surplus to or below the level of 125 kg/hectare. Moreover, the reduction in profit is larger (approximately 350 guilders) than the profit reduction in the N-surplus simulations. This shows that this policy is not preferable either from an environmental or an efficiency point of view. It should be mentioned however that the profit reduction in the N-surplus simulations was underestimated since the costs of keeping accounts of N-flows have not been allowed for. For farmers, no such costs are involved in the case of an N-fertiliser levy. The 18.73% levy on N-fertiliser corresponds to a 0.17 guilder/kg tax on actual N-fertiliser use. By contrast, the 1 guilder/kg and 0.27 guilder/kg levy on N-surplus correspond to a 111% and 30% levy on the price of N per kg N-surplus, respectively.

Policy makers may also be interested in the effects of agricultural policy measures on N-surplus. One such a policy measure is abolishing the set-aside arrangements for large farmers under the new regime for cereals and oilseeds in the EU. Appendix IV (Table IV.2) show that abolishing the set-aside arrangements increases the N-surplus at the sector level by more than 2 kg/hectare. However, the increase for intensive farms in region 1 is almost 5 kg/hectare.

Table 5.3 : Effects of levy on N-surplus with different threshold levels and levy on N-fertiliser (percentage change compared to the base simulation (Appendix IV : Table IV.1).

farm class	CO crops	other outputs	root-crops	pesticides	N-fertiliser	other inputs	Area CO crops	Area set-aside in % total area[1]	Area other outputs	N-surplus[2]	profit
Levy on N-surplus threshold 125 kg/hectare											
3	-14.0	0.4	0.2	1.5	-14.2	1.4	-9.5	0.2	4.2	-40.1	-1.5
4	-1.9	0.2	0.2	1.3	-11.6	2.2	-1.7	4.8	3.6	-28.1	-1.3
sector	-1.0	0.1	0.0	0.4	-5.0	0.4	-0.9	2.2	0.8	-7.8	-0.4
Levy on N-surplus threshold 75 kg/hectare											
1	-3.6	0.0	0.0	0.3	-5.8	0.1	-2.7	0.3	0.7	-7.4	-0.1
2	-0.4	0.0	0.0	0.2	-3.1	0.2	-0.3	2.3	0.3	-3.9	-0.1
3	-7.5	0.2	0.1	0.8	-7.7	0.1	-5.1	0.2	2.3	-19.0	-1.1
4	-1.1	0.1	0.1	0.8	-6.7	0.8	-1.0	4.8	2.2	-16.1	-0.8
sector	-1.0	0.1	0.0	0.4	-5.0	0.3	-0.8	2.2	0.8	-7.8	-0.3
Levy (1 guilder/kg) on N-Surplus threshold 75 kg/hectare											
1	-5.6	0.1	0.1	-8.9	0.3	-4.2	0.3	1.0	1.0	-11.3	-0.2
2	-0.6	0.0	0.0	-4.6	0.4	-0.5	2.3	0.4	0.4	-5.8	-0.1
3	-22.9	0.6	0.4	-23.3	3.2	-15.6	0.2	6.9	6.9	-57.8	-4.3
4	-3.5	0.3	0.3	-21.0	4.8	-3.1	4.8	6.7	6.7	-50.9	-3.3
sector	-2.3	0.1	0.1	-12.0	1.2	-2.0	2.2	1.8	1.8	-18.6	-1.1
Levy on N-fertiliser											
1	-4.0	0.1	0.1	0.3	-6.3	-0.1	-3.0	0.3	0.8	-8.0	-0.4
2	-0.9	0.1	0.0	0.4	-6.4	0.4	-0.9	2.3	0.8	-7.9	-0.5
3	-3.2	0.1	0.1	0.3	-3.2	-0.1	-2.2	0.2	1.0	-8.0	-0.9
4	-0.6	0.1	0.0	0.3	-2.8	0.2	-0.5	4.8	1.1	-6.8	-0.8
sector	-1.1	0.1	0.1	0.4	-5.0	0.3	-1.0	2.2	0.9	-7.8	-0.5

1: Absolute level
2: Absolute change in kg per hectare

Following the introduction of the Long-term Crop Protection Plan (LCPP) in 1991, pesticides use is an other environmental variable that is currently of interest to policy makers (MJP-G, 1991: 101). The simulations performed indicate that pesticides use increases as a result of the policies that aim at reducing N-surplus. The effect on pesticides use should also be taken into account when assessing the environmental gains of different policies.

5.5 Discussion and conclusions

This chapter shows how technical information on the production of an externality can be included in a dual profit function to yield insight in the effects of a tax on the externality. The methodology is applied to a tax on N-surplus which probably will be proposed as a part of future mineral policies for Dutch arable farms. A 0.27 guilder tax per kg N-surplus with a threshold of 75 kg/hectare and a 18% levy on N-fertiliser were found to result in the same reduction of the N-surplus as a 1 guilder tax on N-surplus with a 125 kg/hectare threshold. The N-surplus taxes, however, induce intensive producers to decrease the N-surplus more than extensive producers and should therefore be preferred from an environmental perspective. The N-surplus tax also leads to a lower profit reduction. However, monitoring costs were not taken into account and policy makers should decide whether the costs of monitoring the N-surplus policy outweigh the environmental gains of the N-surplus tax. Of course, it remains true that taxing N-surplus, calculated by the N-surplus formula, is not the same as taxing the pollution generated by the "true" production function for the externality, as specified in our theoretical model.

A number of caveats regarding this model have been mentioned before in Chapter 4. A further problem arising in the simulations reported in this chapter is that there was no information on supply of N through animal manure, which was small but not totally absent in the estimation period. Moreover, only one element of the mineral surplus policies (N-surplus) was dealt with in this chapter. Policy makers are more interested in the effects on arable farming of the entire package of the mineral policies, i.e. the effects of taxes on phosphate and nitrogen surplus.

The contribution of this chapter is to provide a general framework for calculating the effects of a tax on an externality. Although the application to N-surplus policy assumes a linear relationship between inputs and a single externality, the methodology presented allows for multiple externalities and more complex production functions for externalities. The approach pursued in this chapter also enables a comparison of (combinations of) different policies on economic and environmental outcomes.

Chapter 6
Area allocation under price uncertainty : a dual approach

Summary

This chapter uses a Mean-Standard deviation utility function to build a dual model that simultaneously determines area allocation and production/input levels under output price uncertainty. The specification of the Mean-Standard deviation utility function is sufficiently flexible to characterise various risk configurations. Regularity conditions of the indirect utility function (symmetry, convexity) and the producers risk preferences are tested. The framework is applied to a rotating sample of Dutch arable farms.

Dutch arable farmers are found to exhibit the risk configuration Increasing Absolute Risk Aversion and Constant Relative Risk Aversion. All other risk configurations are rejected. A bootstrap resampling method is used to determine the mean and standard deviation of price elasticities and to test the conditions of regularity. Both symmetry and convexity are rejected. Price elasticities show the usefulness of determining both the area allocation and production/input decisions.

6.1 Introduction

Many authors have focused on the problem of area allocation in agriculture. Early literature on area allocation typically assumes that area allocation and the choice of levels of crop specific input and output levels (intensity) are two separate decisions. In later developments, these decisions have been incorporated in one consistent dual framework assuming risk neutrality (Chambers and Just, 1989; Oude Lansink and Peerlings, 1996; Guyomard et al., 1996; Jensen and Lind, 1993). Although empirical evidence has shown that income uncertainty is an important determinant in area allocation (Freund, 1958; Collender and Zilberman, 1985; Babcock et al.,1987; Chavas and Holt, 1990), so far a dual framework has not been developed for simultaneous decisions on area allocation and intensity levels under income risk. Advantages of the dual versus the primal framework have been discussed extensively in the literature (Pope, 1982; Shumway, 1995) and include among others computational convenience, simplicity, estimation efficiency and the possibility to use a broader range of functional forms.

In the literature, uncertainty is included either directly through the specification of an Expected Utility or Mean-Variance function (Collender and Zilberman, 1985; Babcock et al.,1987), or indirectly through the incorporation of wealth variables (Chavas and Holt, 1990). A general weakness of existing approaches (with the exception of Saha et al. (1994) and Saha (1996a)) is that they do not allow the producer to reveal different configurations of (relative and absolute) risk aversion.

This chapter addresses both shortcomings of past approaches through the specification of a Mean-Standard deviation (M-S) utility function that builds on earlier work from Saha (1996a). The M-S utility function is sufficiently flexible to characterise all configurations of risk aversion that are commonly used in the literature. Furthermore, the model simultaneously determines multiple input demand, multiple output supply and the optimal area allocation across crops. A further contribution of this chapter is that it provides a framework for testing the producers' risk attitude as well as conditions of regularity of the indirect utility function underlying the M-S utility function.

Although both yield and price uncertainty are important in arable farming, this chapter focuses on price uncertainty and assumes that farmers face no yield uncertainty. The reason for this is the renewed interest in the effects of price uncertainty following the 1992 CAP reform in EU countries. In case of cereals, fluctuations of world market prices have a greater impact on EU producer prices after the substantial lowering of the intervention price since 1992.

The next section elaborates upon the M-S utility approach, followed by the presentation of the empirical model. A discussion of alternative risk considerations implied by parametric restrictions of the empirical model is the focus of section 6.4. The chapter ends with an application to a rotating sample of specialised Dutch arable farms and concluding comments.

6.2 Theoretical model

In the mean-standard deviation (M-S) framework, the preference ordering of an agents alternatives and utility are determined by the mean (M) and standard deviation (S) of random payoff or income.

$$U = U(M,S) \tag{6.1}$$

Random and mean income are defined as :

$$\tilde{M} = \tilde{p}^T Q - C(w,Q) + E \tag{6.2}$$

$$M = pQ - C(w,Q) + E \tag{6.3}$$

where $\tilde{p}$ and p are random and mean output price vectors respectively, whereas w is an input price vector; Q is a vector of output quantities, C(w,Q), defined as $w^T X$, is a cost function with regular properties (Chambers, 1988:52) and E is exogenous (nonrandom) income. Assuming output prices are the only source of uncertainty that the producer is facing, standard deviation of random income is given by :

$$S = (Q^T Vp Q)^{0.5} \tag{6.4}$$

where Vp is the covariance matrix of output prices. Using (6.3)-(6.4), the M-S utility function can equivalently be expressed as :

$$U^*(p,w,Vp) = \max_Q U\left(p^T Q - C(w,Q),\ (Q^T Vp Q)^{0.5}\right) \tag{6.5}$$

with first order condition :

$$U_M\left(p - C_Q(w,Q)\right) + U_S Vp\, Q = 0 \tag{6.6}$$

which is reexpressed as :

$$p - C_Q(w,Q) = -\frac{U_S}{U_M} VpQ \tag{6.7}$$

$U^*(p,w,Vp)$ is an indirect utility function as opposed to U(M,S) which is the direct utility function. The familiar "price is marginal cost" condition is obtained if either U_S is zero or if price variance is zero (i.e. Vp is a null matrix). $-U_S/U_M$ is a measure reflecting the producers' risk attitude and is the central focus of section 6.4. As under risk neutrality or price certainty, first order condition (6.7) characterises output supply, i.e. by solving for Q to yield Q^* as a function of w and moments of $\tilde{p}$:

$$Q^* = Q^*(p,w,Vp) \tag{6.8}$$

Furthermore, by using the envelope theorem and first order condition (6.7) it can be shown that input demand equations can be obtained by differentiating either $U^*(p,w,Vp)$ or C(W,Q) with respect to input prices w.

$$X(p,w,Vp) = -\frac{\partial U^*(p,w,Vp)}{\partial w} = \frac{\partial C(w,Q^*)}{\partial w} = X(w,Q^*) \tag{6.9}$$

Curvature properties for the indirect Utility function have been derived by Saha (1996b) and Saha and Just (1996). Define the matrix H as:

$$H = Y_r - Y_M Y' \tag{6.10}$$

where Y is (Q,-X), r is (p,w) (i.e. Y and r are vectors of netput quantities and netput prices) and Y_r and Y_M are the first derivatives of Y to r and M respectively; H has dimension *(n x n)* where *n* is the number of inputs and outputs. In Saha (1996b) and Saha and Just (1996) it is shown that matrix H is positive semi-definite and symmetric. A procedure for testing these curvature properties is discussed in section 6.6.

Summarising, in order to obtain a system of input demand and output supply equations under price uncertainty, the following steps have to be taken :

i) Specify a utility function over the mean and standard deviation of random income.

ii) Specify a cost function.

iii) Solve first order conditions for utility maximisation for Q.

iv) Determine input demand equations by differentiating the cost function with respect to w.

The next section will take these steps subsequently.

6.3 Empirical model

Following Saha (1996a) the M-S utility function is specified as :

$$U(M,S) = M^{\gamma} - S^{\theta} \tag{6.11}$$

As shown in section 6.4 this specification allows for a fully flexible characterisation of producers risk attitudes. This section continues with the specification of a short term cost function. The Normalised Quadratic is used here because, overall it came out more favourable on this data set than other functional forms in chapter 2. An other reason for choosing the Normalised Quadratic is its computational ease. Normalised costs[1] are :

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[1] All input prices and costs are normalised by the price of other inputs.

$$C = \alpha_0 + \sum_{i=1}^{2} \alpha_i v_i + \sum_{i=1}^{7} \beta_i z_i + \sum_{i=1}^{3} \lambda_i q_i + \frac{1}{2}\sum_{i=1}^{2}\sum_{j=1}^{2} \alpha_{ij} v_i v_j + \frac{1}{2}\sum_{i=1}^{7}\sum_{j=1}^{7} \beta_{ij} z_i z_j + \frac{1}{2}\sum_{i=1}^{3} \lambda_{ij} q_i q_j + \sum_{i=1}^{2}\sum_{j=1}^{7} \gamma_{ij} v_i z_j + \sum_{i=1}^{2}\sum_{j=1}^{3} \eta_{ij} v_i q_j + \sum_{i=1}^{3}\sum_{j=1}^{7} \mu_{ij} q_i z_j \tag{6.12}$$

where v_i are normalised input prices with i=1 (pesticides) and 2 (N-fertiliser). q_i are quantities of outputs with i=1 (Cereals and Oilseeds (CO crops)), 2 (other outputs) and 3 (rootcrops), z_i are areas, fixed inputs and other variables with i=1 (area CO crops), 2 (area other output), 3 (area of rootcrops), 4 (labour), 5 (capital), 6 (time trend) and 7 (regional dummy =1 for high productivity region). Symmetry in input prices and fixed quantities is imposed by requiring $\alpha_{ij}=\alpha_{ji}$ and $\beta_{ij}=\beta_{ji}$ and $\lambda_{ij}=\lambda_{ji}$.
The first order condition for utility maximisation, is derived as[2] :

$$\gamma M^{\gamma-1}\left[p_i - \lambda_i - \sum_{j=1}^{3} \lambda_{ij} q_j - \sum_{j=1}^{2} \eta_{ij} v_j - \sum_{j=1}^{7} \mu_{ij} z_j\right] - \theta S^{\theta-1}\left[\sum_{j=1}^{3} q_j VP_{ij}\right] = 0 \quad i=1,..,3 \tag{6.13}$$

and is rewritten to yield the i=1,.,3 output supply equations :

$$q_i = \frac{\gamma M^{\gamma-1}\left[p_i - \lambda_i - \sum_{j=1,j\neq i}^{3} \lambda_{ij} q_j - \sum_{j=1}^{3} \eta_{ij} v_j - \sum_{j=1}^{7} \mu_{ij} z_j\right] - \theta S^{\theta-1}\left[\sum_{j=1,j\neq i}^{3} q_j VP_{ij}\right]}{\lambda_{ii}\gamma M^{\gamma-1} + \theta S^{\theta-1} Vp_{ii}}) \tag{6.14}$$

The input equations are derived by differentiating (6.12) with respect to the normalised price of inputs (Shephard's Lemma):

$$x_i = \alpha_i + \sum_{j=1}^{2} \alpha_{ij} v_j + \sum_{j=1}^{7} \gamma_{ij} z_j + \sum_{j=1}^{3} \eta_{ij} q_j \quad i=1,2 \tag{6.15}$$

The equation for the numéraire input can be derived by using the definition of normalised costs : $C = v_1.x_1 + v_2.x_2 + x_3$.

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[2] p is now the normalised mean output price.

$$x_3 = \alpha_0 + \sum_{i=1}^{7} \beta_i z_i + \sum_{i=1}^{3} \lambda_i q_i - \frac{1}{2}\sum_{i=1}^{2}\sum_{j=1}^{2} \alpha_{ij} v_i v_j + \frac{1}{2}\sum_{i=1}^{7}\sum_{j=1}^{7} \beta_{ij} z_i z_j$$
$$+ \frac{1}{2}\sum_{i=1}^{3}\sum_{j=1}^{3} \lambda_{ij} q_i q_j + \sum_{i=1}^{3}\sum_{j=1}^{7} \mu_{ij} q_i z_j \tag{6.16}$$

Finally, CO crops area demand equation is derived by maximising U(M,S) with respect to z_1 and z_2 under the restriction $z_1 + z_2 = a$, where a is the total area of CO crops and other outputs. The assumption that underlies this optimisation is that the area of CO crops and other outputs are employed optimally, whereas the area of rootcrops remains fixed in the short term (see Chapter 4 for more details). The first order condition of this optimisation implies that marginal utilities of z_1 and z_2 are equalised (compare Chambers and Just, 1989). Using first order condition (6.7), however this reduces to the condition :

$$\frac{\partial C(w,Q,z)}{\partial z_1} = \frac{\partial C(w,Q,z)}{\partial z_2} \quad s.t. \quad z_1 + z_2 = a \tag{6.17}$$

which can be solved for z_1 to yield the optimal area allocation to CO crops :

$$z_1 = \frac{1}{\beta_{11} + \beta_{22} - 2\beta_{12}} \times$$
$$\left[(\beta_2 - \beta_1) + (\beta_{22} - \beta_{21})a + \sum_{j=1}^{2} (\gamma_{2j} - \gamma_{1j})v_j + \sum_{j=4}^{7} (\beta_{2j} - \beta_{3j})z_j + \sum_{j=1}^{3} (\mu_{2j} - \mu_{1j})q_j \right] \tag{6.18}$$

6.4 Risk attitude

Using the utility function that has been specified in the previous section, the producers risk attitude $-U_S/U_M$ is given by :

$$A(M,S) = -\frac{U_S}{U_M} = \frac{\theta}{\gamma} M^{1-\gamma} S^{\theta-1} \tag{6.19}$$

Following Saha (1996a), it can be shown that this specification of the utility function is sufficiently flexible to characterise various combinations of relative and absolute risk aversion.

1) Assuming that $U_M > 0 \ \forall \ M$, risk aversion, risk neutrality and risk affinity correspond to $\theta > 0$, $= 0$ and < 0 respectively.
2) $A_M < 0$ ($=0$, >0) represents decreasing (constant, increasing) *absolute* risk aversion. This translates in the parameter restriction $\gamma > 1$ ($= 1$, < 1).
3) $A_t(tM,tS) < 0$ ($= 0$, > 0) $\forall t>0$ represents decreasing, constant and increasing *relative* risk aversion. This holds for $\gamma > \theta$, $\gamma = \theta$ and $\gamma < \theta$ respectively.

Table 6.1 presents an overview of different risk configurations and corresponding parameter restrictions.

A few comments on the specification of the utility function in (6.11) are in order. The specification implies that risk preferences solely depend on parameter values such that risk preferences can be tested globally. While this characteristic may be desirable if the focus is on testing risk preferences, at the same time it conceals differences in risk preferences between farmers caused by e.g. farmer specific preferences and farm specific endowments of fixed inputs or exogenous income. Estimating the parameters of the utility function for different groups of farmers is a way to capture this.

6.5 Data and Estimation

Data

Data on specialised arable farms[3], covering the period 1974-1992, were obtained from a stratified sample of Dutch farms which kept accounts on behalf of the LEI-DLO farm accounting system[4]. Farms stay in the panel for only five to six years, so the panel is incomplete. The data set used for estimation contained 3571 observations on 784 farms.

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[3] Farms with more than 80% of output coming from marketable crops.

[4] A complete description of the sample can be found in LEI-DLO (1992).

Three outputs (CO crops, rootcrops and other outputs) and three variable inputs (pesticides, N-fertiliser and other inputs) are distinguished. CO crops consist of winter-wheat, barley, oats and oilseeds. The cereals included account for approximately 85% of the total area of cereals on the farms in the sample. Rootcrops include sugar beet, ware potatoes, seed potatoes and starch potatoes. Other outputs are combined in an aggregate index covering all other marketable crops not accounted for in the previous category, and animal output. Other inputs consist of services, non-nitrogenous fertiliser, seed and planting materials, purchased feed input, energy and other variable inputs.

Fixed inputs are the rootcrop specific area, the total area of CO crops and other outputs, labour and capital. The areas are measured in hectares allocated to every output. Labour is measured in quality-corrected man years, and includes family as well as hired labour. Capital includes capital invested in machinery and livestock and is measured at constant 1980 prices.

Exogenous income (E) is defined as income from social security payments and non-farm assets and is also deflated by the price of other inputs.

Regional differences, e.g in soil quality, are accounted for by including a dummy variable (=1 for the high productivity region, 0 for the low productivity region).

Tornqvist price indexes were calculated for the three outputs and the other input. The price indexes vary over the years but not over the farms, implying that differences in the composition of a netput or quality differences are reflected in the quantity (Cox and Wohlgenant, 1986). Implicit quantity indexes were obtained as the ratio of value to the price index.

Output prices are not known at the time decisions are made on planting and the use of variable inputs, so expected rather than realised prices have to be used. Expected output prices were constructed by applying an AR(1) filter to CO crops and other outputs and an AR(2) filter to rootcrops. All prices are deflated by the price of other inputs.

Variance of mean expected price of output i at time t $(var_t(p^i))$ and covariance between mean expected prices of output i and j $(cov_t(p^i p^j))$ are generated in a way similar to Coyle (1992) and Chavas and Holt (1990)[5] :

$$var_t(p^i) = 0.67(p^i_{t-1} - E_{t-2}p^i_{t-1})^2 + 0.33(p^i_{t-2} - E_{t-3}p^i_{t-2})^2 + 0.17(p^i_{t-3} - E_{t-4}p^i_{t-3})^2 \tag{6.20}$$

$$\begin{aligned} cov_t(\bar{p}^i p^j) = {} & 0.67(p^i_{t-1} - E_{t-2}p^i_{t-1})(p^j_{t-1} - E_{t-2}p^j_{t-1}) + 0.33(p^i_{t-2} - E_{t-3}p^i_{t-2})(v^j_{t-2} - E_{t-3}p^j_{t-2}) \\ & + 0.17(p^i_{t-3} - E_{t-4}p^i_{t-3})(p^j_{t-3} - E_{t-4}p^j_{t-3}) \end{aligned} \tag{6.21}$$

Note that this particular weighting scheme assumes that the weight decreases by approximately 50% each year. Prices of CO crops have been supported by an intervention price system during the period that the data set covers. The intervention price resulted effectively in a truncation of the price distibution of CO crops such that downward price variability was reduced. Similarly, prices for rootcrops and other outputs are truncated at zero, since output prices are nonnegative. In order to account for the truncation of output prices due to the intervention price and the nonnegativity restriction, all variances, covariances and expected producer prices have to be corrected. This chapter uses the methodology that is layed out in Chavas and Holt (1990) to account for truncation in the price distibution. Taking truncation into account results in expected prices for outputs that are higher than the mean price that follows from the AR(1) and AR(2) processes.

Estimation

Equations (6.14)-(6.16) and (6.18) constitute a nonlinear system of simultaneous equations with possible correlation of error terms across equations. Full Information Maximum Likelihood (FIML) is the estimator that is employed since it accounts for possible

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[5] Chavas and Holt (1990) and Coyle (1992) used 0.50, 0.33 and 0.17 as relative weights for t-1, t-2 and t-3 respectively. These weights were also used initially in this study, but the estimation was hindered by convergence problems. Using weights, 0.67, 0.33 and 0.17 the estimation model converged rapidly. The results, regarding the nature of risk preferences are, however, not effected by this change in the weighting scheme. Alternatively, (co)variances can be generated, using (1) a multivariate GARCH model (Bollerslev et al., 1988; Engle et al., 1990) or (2) an adaptive expetations approach (Pope and Just, 1991).

simultaneity bias as well as possible cross equation correlation of error terms. Endogenous variables in the estimation model are q_i ($i=1,..,3$), x_i ($i=1,2$), z_1, M and S. The estimator that is applied attaches an equal weight to cross section and time series variation of the data[6].

6.6 Results

The results of the estimation of the system of output supply, input demand and area allocation equation can be found in the Appendix V (Table V.2). Approximately 80% of the parameters is found to be significant from zero at the critical 5% level. Interestingly, also the parameters that relate to the utility function, γ and θ, are found to be very significant (at 5%). An easy test for risk neutrality is provided by testing $H_0{:}\theta=0$ against the alternative $H_1{:}\theta\neq0$. Table V.2 shows that this hypothesis is firmly rejected at the critical 5% level.

Using the estimates of this model, alternative risk configurations as described in section 6.4 are tested. Table 6.1 shows that all hypotheses, except for the CARA/CRRA hypothesis involve two simultaneous inequality restrictions, or a combination of an equality and inequality restriction. The Bonferroni t-statistics can be used to test for the significance of the individual parameter restrictions, given that H_0 involves multiple restrictions (Morey, 1986; Miller, 1966). If the overall level of significance of the test is 0.05, having two inequality restrictions (or one equality restriction and one inequality restriction), implies that the Bonferroni t-statistics for the individual t-ratios are given by the Student t-distribution at the critical 0.025 level (0.05/2). The critical regions for parameter restrictions I and II are given in the final column of Table 6.1.

t-values for parameter restriction I and II are -139.80 and 0.01 respectively. Therefore, all risk configurations are rejected at the critical 5% level except for the

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[6] The availability of panel data usually leads to a panel data estimation method (fixed or random effects) as a natural choice. The characteristic of a panel data estimation method is that it weighs the cross section and time-series variation differently compared to non-panel data estimation methods (Greene, 1993 : 472-473). Estimation of a fixed or random effects model with a large number of farms is however only feasible by making the implausible assumption that fixed or random effects only appear in the input demand equations (see also Chapter 4).

configuration Increasing Absolute Risk Aversion/Constant Relative Risk Aversion. The implication of IARA is that high income Dutch arable farmers are more risk averse than low income arable farmers. Accordingly it may be expected that the cropping pattern of high income arable farmers involves less risky crops than the cropping pattern of low income arable farmers. Although Decreasing Absolute Risk Aversion is often considered as a stylised fact, evidence for Increasing Absolute Risk Aversion has been found before in the literature (Wolf and Pohlman, 1983). It should also be noted that many of the

Table 6.1 : Tests of alternative risk configurations[a]

Hypothesis	Parameter restrictions		Critical regions	
	I	II	I	II
DARA/DRRA	$\gamma>1$	$\gamma-\theta>0$	[1.96,∞ >	<1.96,∞ >
DARA/CRRA	$\gamma>1$	$\gamma-\theta=0$	[1.96,∞ >	<-∞,-2.24] [2.24,∞ >
DARA/IRRA	$\gamma>1$	$\gamma-\theta<0$	[1.96,∞ >	<-∞,-1.96]
CARA/DRRA	$\gamma=1$	$\gamma-\theta>0$	<-∞,-2.24] [2.24,∞ >	<1.96,∞ >
CARA/CRRA	$\gamma=1$	$\gamma-\theta=0$	<-∞,-2.24][2.24,∞ >	<-∞,-2.24][2.24,∞ >
CARA/IRRA	$\gamma=1$	$\gamma-\theta<0$	<-∞,-2.24] [2.24,∞ >	<-∞,-1.96]
IARA/DRRA	$\gamma<1$	$\gamma-\theta>0$	<-∞,-1.96]	[1.96,∞ >
IARA/CRRA	$\gamma<1$	$\gamma-\theta=0$	<-∞,-1.96]	<-∞,-2.24] [2.24,∞ >
IARA/IRRA	$\gamma<1$	$\gamma-\theta<0$	<-∞,-1.96]	< -∞,-1.96]

a) DARA, CARA and IARA represent Decreasing, Constant and Increasing Absolute Risk Aversion; DRRA, CRRA, IRRA represent Decreasing, Constant and Increasing Relative Risk Aversion.

functional forms used in the literature to test for the structure of risk preferences, preclude the presence of IARA a priori. An explanation for the fact that Dutch arable farmers exhibit IARA may be that small size farms are relatively more dependent for their income on risky crops as potatoes (in rootcrops) than large size farms.

The implication of CRRA is that an ad valorem income tax does not influence the size of the coefficient of risk aversion ($-U_S/U_M$). This means that the possibility for farmers to deduct losses in previous years from profits in the current year (resulting in a lower marginal tax rate) does not influence current behaviour (Sandmo, 1971). CRRA preferences could also not be rejected by e.g. Landskroner (1977), Pope and Just (1991), Szpiro (1986) and Saha (1996a).

Price elasticities and standard errors are presented in Table 6.2. A few comments on their computation are in order. It can be seen that the estimation equations are highly nonlinear in endogenous variables and parameters and an analytical solution for output supply and input demand equations does not exist, because they appear as right hand side variables in the equations for M and S. Consequently it is impossible to express the system of structural equations in its reduced form and derive an explicit solution for all price elasticities. Price elasticities and elasticities of intensities where therefore derived implicitly by solving[7] the system for different sets of price levels[8], using the solution algorithm for nonlinear simultaneous systems of equations that is available in SAS. Mean price elasticities and standard deviations are determined using a bootstrap resampling method (Eakin et al., 1990).

Price elasticities presented in Table 6.2 are total price elasticities : they represent the intensity and area effect of a price change. Own price elasticities of outputs are all positive and significant; price elasticities of inputs are negative and significant for all but N-fertiliser. CO crops and other outputs are substitutes given their large negative cross price elasticities. The importance of including area allocation is obvious from the cross price elasticities since reallocation of areas contributes significantly to the substitution between CO crops and other outputs : an increase in the price of CO crops lowers the area of other outputs and vice versa. An increase in the price of rootcrops increases the area of CO crops (and lowers that of other outputs), but lowers the intensity of CO crops

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7 The system of equations (6.14)-(6.16), (6.18) and the equations for M and S have to be solved simultaneously. Convergence was however not obtained by solving all endogenous variables simultaneously; convergence was obtained by solving (6.14)-(6.16), (6.18) and M. A two step solution was therefore obtained by first solving conditional on S and, second calculating a new S with these solution values and solving again conditional on S.

8 The system was solved for exogenous variables at the sample mean, and after a 1% increase of the price of input or output i. The difference in the input and output quantities of the first and the second solution can be used to calculate elasticities of outputs, inputs and areas with respect to the of i.

(and of other outputs) through a reallocation of fixed, but allocatable resources, labour and capital. The positive (negative) area allocation effect of CO crops (other outputs) dominates (strengthens) the negative reallocation effect of labour and capital. The positive effect of rootcrops price on the area of CO crops is a result of the fact that rootcrops production needs a sufficiently large area of cereals.

All variable inputs are complements (with the exception of a small and nonsignificant substitution relation between other inputs and N-fertiliser). The negative impacts of pesticides and N-fertiliser on CO crops area indicate that CO crops are relatively more dependent on these inputs than other outputs are. An increase in exogenous income has an overall negative impact on intensity and favors the area of (less risky) CO crops to the detriment of the area of other outputs.

Table 6.2 : Total price elasticities at the sample mean (Estimated standard deviations in parentheses).

	CO crops	Other outputs	Root-crops	Pestici-des	N-fer-tiliser	Other inputs	Ex. income
CO crops	2.90* (0.08)	-1.95* (0.05)	0.11 (0.01)	-0.30* (0.05)	-0.09* (0.03)	-0.67* (0.08)	0.03* (0.00)
Other outputs	-1.73* (0.05)	3.72* (0.10)	-0.30 (0.01)	-0.10* (0.02)	0.03 (0.01)	-1.58* (0.05)	-0.05* (0.00)
Rootcrops	-0.31* (0.01)	-0.29 (0.01)	0.52* (0.02)	0.07* (0.00)	0.06* (0.00)	0.02* (0.02)	-0.09* (0.00)
Pesticides	0.50* (0.12)	0.34* (0.04)	0.08* (0.01)	-0.60* (0.13)	-0.07 (0.05)	-0.23 (0.15)	-0.03* (0.00)
N-fertiliser	0.59* (0.16)	0.02 (0.06)	-0.16* (0.01)	-0.27* (0.14)	-0.08 (0.15)	-0.12 (0.23)	0.03* (0.00)
Other inputs	0.18* (0.04)	1.05* (0.03)	0.10* (0.02)	-0.02 (0.04)	0.02 (0.02)	-1.27* (0.07)	-0.05* (0.00)
CO crops area	1.69* (0.06)	-2.14* (0.05)	0.14* (0.01)	-0.17 (0.10)	-0.43* (0.06)	0.88* (0.11)	0.03* (0.00)
Other outputs area	-2.11* (0.08)	2.67* (0.07)	-0.17* (0.01)	0.21 (0.12)	0.54* (0.07)	-1.10* (0.14)	-0.04* (0.00)

* Significant at 5%

Since convexity and symmetry conditions do not directly translate into parameter restrictions, using the M-S model that is developed in this chapter, an alternative approach is necessary. The approach adopted in this chapter employs a bootstrap resampling method (Eakin et al., 1990) to generate 1000 observations of the matrix H in (6.10). Next OLS is used to estimate the mean and standard deviation of individual components and perform tests on symmetry and convexity.

The test on symmetry involves 15 parameter restrictions on the individual components of H. These restrictions can be usefully tested using an F-test. The statistic that is found for H_0: $H_{ij}=H_{ji}$ $\forall i,j$ is 96696.60 which is larger than $F^{15}_{\infty,0.05}$ =1.67, so H_0 is firmly rejected at the critical 5% level. The test on convexity of H in prices uses the fact that almost every symmetric positive definite matrix can be represented as a nonlinear factorisation LDL' where L is a unit lower triangular matrix and D is a diagonal matrix whose elements are the (nonnegative) Choleski values. Testing for convexity however requires that symmetry is imposed. The Choleski values of H are reported in Table 6.3. One Choleski values is negative. The significance of this violation can be tested, using the Bonferroni t-statistics. If the overall level of significance of the test is 0.05 then, having six simultaneous inequality restrictions implies that the one tailed critical value of the test is 0.05/6 = 0.0083. The null hypothesis H_0: $D_{ii}\geq 0$, $i=1,..,6$, against the alternative H_1 : $D_{ii}<0$ for at least one i is rejected if at least one t-value is smaller than -2.39. It can be seen in Table 6.3 that negative Choleski value is significant at the 5% level. Therefore the null hypothesis that the matrix H is positive semidefinite is rejected.

Table 6.3 : Estimated Choleski values and t-statistics.

Parameter	Estimate	t-statistic
D_{11}	140.16	1150.29
D_{22}	174.31	633.76
D_{33}	86.95	184.16
D_{44}	5.95	101.37
D_{55}	0.33	1.19
D_{66}	-28.49	-8.83

Testing for symmetry and curvature conditions under risk, is an area that has remained largely unresolved in the literature. Coyle (1992) has tested for symmetry in a restrictive linear mean-variance model and rejected it statistically. A recent survey of the relatively rich literature of empirical applications of duality theory under risk neutrality by Shumway (1995), shows that also here, curvature conditions and especially symmetry, are often rejected. In conclusion, the failure of the model that was presented in this chapter, to satisfy conditions of regularity is not exceptional.

6.7 Discussion and conclusions

This chapter has presented a dual model that simultaneously determines area allocation and intensity levels under price uncertainty. The Mean-Standard deviation utility function that underlies the producers decisions is sufficiently flexible to characterise various risk configurations. The framework is applied to a rotating sample of Dutch arable farms.

Dutch arable farmers are found to exhibit the risk configuration Increasing Absolute Risk Aversion and Constant Relative Risk Aversion. All other risk configurations are rejected. A bootstrap resampling method is used to determine the mean and standard deviation of price elasticities and to test the conditions of regularity. Both symmetry and convexity are rejected. Price elasticities show the usefulness of determining the area allocation and intensity levels simultaneously.

Although the framework of the model that is developed in this chapter is dual, since technology can be recovered from the parameters of the cost function, the model partially loses advantages of dual forms as computational ease and simplicity by including the first order conditions for utility maximisation. Estimation efficiency and the possibility to use a broader range of functional forms are, however maintained.

A natural extension of the M-S model in this chapter is the incorporation of output uncertainty. The specification of cost functions under output uncertainty has been addressed by Chavas and Pope (1994) and an empirical implementation can be found in Pope and Just (1996). Qualitative properties of the firms optimal choices under price and production risk have been explored by Saha (1995) and Coyle (1996).

Chapter 7

Asymmetric Adjustment of Dynamic Factors at the Firm Level

Summary

This chapter provides a framework for consistent estimation of a dynamic dual model of investment for the case where data reveal zero and non-zero investments. The threshold model that is developed maintains that investments are zero if the shadow value of machinery is between a lower and an upper threshold. Separate equations are estimated for the investment and the disinvestment regime. A significant difference between the parameters of the investment and disinvestment equations is found; the test for differences in individual parameters indicates a significant difference for two of the twelve parameters. Short and long term price elasticities conditional on the regime that applies are derived. The adjustment rates for machinery reveal adjustment terms of 7-8 years for disinvestments and 14 years for investments.

7.1 Introduction

Most theoretical and empirical research on dynamic adjustment models focus on the modelling of the adjustment costs and their implications for investment and expansion strategies.[1] Despite the differences in the methodologies (e.g., dynamic primal versus dynamic dual, static versus nonstatic price expectations) the analytical framework

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[1] Eisner and Strotz (1963), Lucas (1967), Gould (1968), Treadway (1969, 1970, 1971), Rothschild (1971), Mortensen (1973), McLaren and Cooper (1980), Epstein (1981) and Caputo (1990) develop a consistent theoretical background for the adjustment cost model. Recent empirical models focus on testing for the presence of adjustment costs and evaluating the impact of the adjustment behavior on production decision making [e.g., Pindyck and Rothemberg (1983), Epstein and Denny (1983), Vasavada and Chambers (1986), Shapiro (1987), Howard and Shumway (1988)]. More recent work generalizes production structure and growth measures to the dynamic case [e.g., Luh and Stefanou (1991, 1993), Fernandez et al (1992), Stefanou et al (1992), Fousekis and Stefanou (1996)].

maintains an intertemporal profit maximising (or cost minimising) assumption under which a linear accelerator adjustment mechanism is commonly maintained for the determination of dynamic factor demand functions.

Previous studies of the firm facing adjustment costs are constrained by the assumption of symmetric adjustment responses; i.e., the same degree of sluggishness exists in the quasi-fixed factor adjustment process for expansions and contractions. Conceivably, it is often easier to scale back one's operations during hard times than it is to expand during prosperous times to a scale of operation that is out the manager's experience. The notion of asymmetric adjustment has been emphasised by Goodwin (1951) in his work on nonlinear accelerator principle as the factor in explaining the persistence of business cycles.[2] More recently Neftci (1984), Hamilton (1989), Madan and Prucha (1989), Pfann and Palm (1993) and Pfann (1996) observe business cycles fluctuating along long-run secular trends using economic time series models incorporating discrete regime changes.

In the standard approach to modelling quasi-fixed factor demand, zero investments are optimal if the shadow value of the quasi-fixed factor is zero. Observations from firm level data where zero investment are observed questions the consistency of the standard approach to modelling firm level decision making. A theoretical problem arising is that the first order condition for optimisation of the value functions implicit in the dual approach is not necessarily satisfied. Data are censored in the presence of zero investments leading to econometric problems for both the primal and dual approach. This implies the standard assumption of independent and identically distributed errors no longer applies resulting in biased estimates if not corrected.

The modelling of asymmetry, nonlinearity and zero gross investment are combined by applying a regime shifting method to formulate a generalised dynamic adjustment cost model. The generalisation endogenises capital accumulation and provides a natural linkage between firm size and exogenous economic variables (e.g., netput price changes, government policies). In this sense, structural change is inherent in the evolution described by

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[2] In the classical business cycle theories, the accelerator principles are often used as the single most important cause of the cyclical fluctuations. Kalecki (1935) initiated using stock-adjustment investment functions to feature the cycles. Kaldor (1940), Hicks (1950) and Goodwin (1951) interject the nonlinearity notion into the investment function to both explain the cycles and trace out the time path of an actual cycle which is asymmetrical. Another nonlinear approach developed by Smithies (1957) uses the ratchet treatment to incorporate the asymmetry in generating both the cyclical and secular aspects of the GNP movements.

this optimisation process. The asymmetric model nests symmetric adjustment rates and presents the opportunity to test statistically for the superiority of specifying asymmetric adjustment rates.

This chapter addresses the shortcomings of past approaches through the specification and estimation of a threshold model to characterise investment demand. The dual framework is employed which does not require a closed form solution for the Euler equation to derive factor demand equations.[3] The threshold model maintains investments are zero if the shadow value of capital is between a lower and an upper threshold. This model is estimated in two stages. The first stage determines the decision whether to invest, disinvest or do nothing. This information is used to correct the error terms in the second stage which comprises the estimation of a system of output supply and variable and quasi-fixed factor demand equations. Since the value function does not necessarily exist for zero investments, only the observations for which investments are non-zero are used in the second stage.

The next section elaborates upon the standard dual approach and illustrates how the maintained assumptions of the adjustment cost function allow for zero investments as optimal under restrictive conditions. This is followed by the presentation of a threshold model explaining the occurrence of zero investments along with discussion of the empirical model, econometric specification and estimation considerations. An application to a rotating sample of specialised Dutch cash crop farms is the focus of the application followed by concluding comments.

7.2 The Standard Dual Model

The standard dual model and the underlying adjustment cost function provide a reference point for the development of the threshold model. The standard dual model starts with the maximisation of the discounted flow of profit for the firm producing multiple outputs using variable and multiple quasi-fixed factors taking the form

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[3] Whereas a solution is tractable for a standard quadratic adjustment cost function, the problem becomes highly complex for more flexible specifications of adjustment costs, e.g. interactions between investments and the capital stock or third order effects (Pindyck and Rotemberg, 1993; Shapiro, 1986).

$$J(v,w,K,Z,t) = \max_{I} \int_{t}^{\infty} e^{-rs}[\pi(v,K(s),Z(s),\ s) - w'K - C(I(s))]ds \tag{7.1}$$

where K is a vector of quasi-fixed inputs and I is the corresponding gross investments; π is defined as vQ; v and w are (vectors of) market prices of netputs and quasi-fixed inputs, respectively; Q is a vector of netput quantities (positive for outputs, negative for inputs) and Z a vector of fixed inputs; s reflects technological progress as a time trend; and C(I) is the adjustment cost function with the following properties

(A.1) continuous and differentiable

(A.2) strictly convex

(A.3) a. $C(0) = 0$

b. $C_I(0) = 0$

(A.4) symmetric around $I=0$

Figure 1 presents an adjustment cost function fulfilling these assumptions. The symmetry property ensures investments and disinvestments involve the same costs at equal absolute levels of gross investment, I. In the current period, the firm is assumed to have static expectations concerning real prices, fixed inputs and technology and these expectations will prevail in perpetuity[4]. Price expectations are static in the sense that relative prices observed in each base period are assumed to persist indefinitely. As the base period changes, expectations are altered and previous decisions are no longer optimal. Only that part of the decision corresponding to the base period is actually implemented.

The Hamilton-Jacobi equation of the optimisation problem in (7.1) has the form

$$rJ(v,w,K,Z,t) = \max_{I}\{\pi(v,K,Z,t) - w'K - C(I) + (I-\delta K)'J_k\} + J_t \tag{7.2}$$

Assuming an interior solution, the first order condition of this optimisation is

[4] Static real price expectations is a widely held assumption in dynamic models in agriculture. Chambers and Lopez (1984) justify this assumption by noting that outputs are storable and storage costs are small in comparison with the value of the commodities. Under these conditions, it would be rational for small and medium-sized firms to rely on static expectations because of the costs of acquiring information.

$$C_I = J_k \tag{7.3}$$

implying the shadow price of capital equals the marginal adjustment cost. Netput equations are derived by differentiating the optimised Hamiltonian-Jacobi equation in (7.2) with respect to v and applying the envelope theorem to yield

$$Q = rJ_v - J_{kv}\dot{K} - J_{tv} \tag{7.4}$$

Investment demand equations can be derived similarly by differentiating the optimal value function with respect to quasi-fixed factor prices and applying the envelope theorem leading to

$$\dot{K} = J_{kw}^{-1}\,(rJ_w + K - J_{tw}) \tag{7.5}$$

The properties of the value function, J, depend crucially on the characteristics of the underlying adjustment cost function *(A.1)* - *(A.4)*.

7.3 The Threshold Model

The standard dual model suggests zero investments only occur if the shadow value of capital equals zero. However, this is not consistent with the observation from firm level data where zero investments occur frequently.

Hsu and Chang (1990) show that a discontinuity of the adjustment cost function at I=0 is sufficient for asset fixity to occur. The occurrence of a discontinuity arises when buyers are not able to evaluate the quality of the factor/product properly (Dixit and Pindyck, 1994). The quality for used machinery on the market is below the average quality of machinery in the sector since sellers are reluctant to sell an item with an above average quality. This significantly lowers the price for used machinery. Hence, a lower price can be seen as an adjustment cost. A discontinuity may also arise as a result of government regulation (Dixit and Pindyck, 1994). A firm may have to repay an investment subsidy if it decides to sell the asset within the limits set by the subsidy program. Properties *(A.1)* and *(A.3b)* no longer hold if a discontinuity in the adjustment cost function occurs.

Figure 1: Standard adjustment cost function

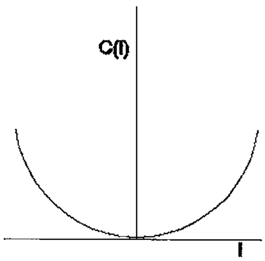
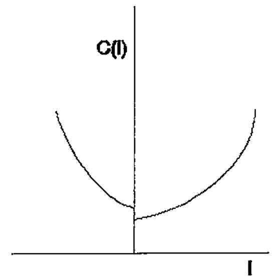


Figure 2 : Threshold model with fixed adjustment costs



In a more general framework than Hsu and Chang (1990), Abel and Eberly (1994) indicate that fixed adjustment costs may also give rise to the occurrence of zero investments thereby relaxing *(A.3a)*. Figure 2 illustrates an adjustment cost function no longer satisfying properties *A.1* and *A.3*. The optimality condition is $J_k = C_I$. With a discontinuity occurring at $I=0$, $C_I(0)$ does not necessarily exist and investments are zero for the range of shadow values described by

$$\lim_{I \to 0^+} C_I(I) > 0 \qquad\qquad (7.6)$$
$$\lim_{I \to 0^-} C_I(I) < 0$$

Equation (7.6) depicts the lower and upper limit values of $C_I(0)$ while bearing in mind the first order conditions in (7.3) makes it clear why zero investments are likely to occur when the adjustment cost function has the form as in figure 2. With the symmetry condition relaxed in the adjustment cost function, the investment regime differs from the disinvestment regime. Following Abel and Eberly (1994) this adjustment cost function results in the following decision rule for the optimal investment regime

$$\dot{K} = \begin{array}{ll} \dot{K} < 0 & \text{if } J_k < q_1 \\ \dot{K} = 0 & \text{if } q_1 \leq J_k \leq q_2 \\ \dot{K} > 0 & \text{if } J_k > q_2 \end{array} \qquad (7.7)$$

where q_1 and q_2 are threshold levels for the shadow price of capital. Investments are negative if the shadow value of capital is smaller than q_1 and investments are positive for all shadow values larger than q_2.

7.4 Empirical Model

The previous literature on dynamic investment demands has employed the Normalised Quadratic specification for the optimal value function (Vasavada and Chambers, 1986; Stefanou et al., 1992). This functional form has the advantage of empirical simplicity at the cost of using an arbitrary numeraire input or output in order to impose linear homogeneity in prices. As a result, estimation results are not invariant with respect to the choice of the numeraire (Mahmud et al, 1987). The Normalised Quadratic is more troublesome in the context of this chapter since the specification of external adjustment costs precludes the derivation of the equation of the numeraire input. The Symmetric Normalised Quadratic (Kohli, 1993; Diewert and Wales, 1987) has the advantage of avoiding the derivation of the numeraire input and estimation results are invariant with respect to choice of the numeraire (see also Chapter 2). The value function takes the following form

$$\begin{aligned} J(v,w,z,K,t) = {} & (a_1 a_2) \begin{bmatrix} v \\ w \end{bmatrix} + \frac{1}{2}(\theta' v)^{-1} \, (vw) \begin{bmatrix} A & C \\ C' & B \end{bmatrix} \begin{bmatrix} v \\ w \end{bmatrix} \\ & + \frac{1}{2}(\theta' v) \, (zKt) \begin{bmatrix} D & G & H \\ G' & E & L \\ H' & L' & F \end{bmatrix} \begin{bmatrix} z \\ K \\ t \end{bmatrix} + (vw) \begin{bmatrix} O & P & R \\ S & M^{-1} & U \end{bmatrix} \begin{bmatrix} z \\ K \\ t \end{bmatrix} \end{aligned} \tag{7.8}$$

where θ represents a vector of average shares of netputs in total costs plus revenues. In order to identify all parameters, additional restrictions have to be imposed :

$$\sum_{i=1}^{5} A_{ij}\bar{v}_i = 0 \quad j=1,..,5$$
$$\sum_{i=1}^{5} C_{ij}\bar{v}_i = 0 \quad j=1,2$$

where $\bar{v}_i$ is an arbitrary point or observation (in this chapter it is the sample mean).

Using (7.5), the demand equation for investments can be derived as

$$\dot{K}=(ru+M)K+rM(a_2+(\theta v)^{-1}(Bw+Cv)+Sz+Ut) \; - \; MU \tag{7.9}$$

implying a multivariate linear accelerator mechanism

$$\dot{K}^* = (ru + M)(K - K^*) \tag{7.10}$$

where K^* is the optimal stock of K,

$$K^* = rN(a_2+(\theta v)^{-1}(Bw+Cv)+Sz+Ut) - NU \tag{7.11}$$

and N is $-[ru+M]^{-1}M$. The shadow value of capital is[5]

$$J_k = a_4+(\theta' v)(G'z+E'K+L't)+M^{-1'}w+P'v \tag{7.12}$$

Assume the case of two quasi-fixed factors, K_1 and K_2, where asymmetric adjustment is possible for K_2. Using the demand equation for investment, $\dot{K}_2$, and the shadow value of K_2, these equations are compactly expressed as

$$\begin{aligned} \dot{K}_2 &= \gamma_2 X \\ J_{k_2} &= \beta_2 X \end{aligned} \tag{7.13}$$

where X is *(v, w, z, K, t)*. The netput equation is

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[5] Note that q_1 and q_2 in the Abel and Eberly model include the price of capital.

$$Q^* = r(a_1 + (\theta' v)^{-1}(A'v + C'w) - \frac{1}{2}\theta(\theta' v)^{-2}(vw)\begin{bmatrix} A & C \\ C' & B \end{bmatrix}\begin{bmatrix} v \\ w \end{bmatrix} + \frac{1}{2}\theta(zKt)\begin{bmatrix} D & G & H \\ G' & E & L \\ H' & L' & F \end{bmatrix}\begin{bmatrix} z \\ K \\ t \end{bmatrix} \tag{7.14}$$

$$+ \; O'z + P'K + R't) - (P' + \theta(G'z + E'K + L't))\dot{K} \; - \; R - \; \theta(HLF)\begin{bmatrix} z \\ K \\ t \end{bmatrix}$$

The decision rule in (7.7) translates into the following model of investments

$$\dot{K}_2^- = \gamma_2^- X + u_1 \tag{7.15}$$

$$\dot{K}_2^+ = \gamma_2^+ X + u_2 \tag{7.16}$$

$$\begin{aligned} \dot{K}_2 &= \dot{K}_2^- && if \;\; I_2 < 0 \\ \dot{K}_2 &= -\delta K_2 && if \;\; I_2 = 0 \\ \dot{K}_2 &= \dot{K}_2^+ && if \;\; I_2 > 0 \end{aligned} \tag{7.17}$$

where u_1 and u_2 are the error terms of the disinvestment and investment equation. The investment function is allowed to be different from the disinvestment function leading to a tobit switching regression model. Since negative observations on investments are used to estimate equation (7.15) and positive investments to estimate equation (7.16), two censored equations are implied. Consistent estimates of γ^-_2 and γ^+_2 require determination of the expected error terms

$$\begin{aligned} &E(u_1 \mid \dot{K}_2 = \dot{K}_2^-) \\ &E(u_2 \mid \dot{K}_2 = \dot{K}_2^+) \end{aligned} \tag{7.18}$$

This switching regression model differs from the standard switching regression model since observations on zero investments are not used. The first step in the estimation of this tobit switching regression model requires the determination of the conditional expectations of u_1 and u_2. This can be accomplished in the same way as in the case of a standard switching regression model except there are two limits, 0^- and 0^+, instead of one. Defining a dummy variable Δ

$$\begin{array}{ll} \Delta=0 & if\ I_2<0 \\ \Delta=1 & if\ I_2=0 \\ \Delta=2 & if\ I_2>0 \end{array} \tag{7.19}$$

and expressing (7.15)-(7.17) as the two limits in the tobit switching regression model[6]

$$\begin{array}{ll} \dot{K}_2^- = \gamma_2^- X + u_1 & if\quad u < q_1 - \beta X \\ \dot{K}^0 = -\delta K_2 & if\quad q_1 - \beta X \leq u \leq q_2 - \beta X \\ \dot{K}_2^+ = \gamma_2 X + u_2 & if\quad u > q_2 - \beta X \end{array} \tag{7.20}$$

The decision about the investment regime is now determined by an ordered probit model. Assume u_1, u_2, and u have a trivariate normal distribution and let σ_{1u} and σ_{2u} denote the covariances of u and u_1, u_2, respectively. The conditional expectations of u_1 and u_2 are derived from the estimates of the ordered probit model

$$E(u_1 \mid \dot{K}_2 = \dot{K}_2^-) = -\sigma_{1u} \frac{\phi(-\hat{\beta}X)}{\Phi(-\hat{\beta}X)} = -\sigma_{1u}\hat{W}_1 \tag{7.21}$$

$$E(u_2 \mid \dot{K}_2 = \dot{K}_2^+) = \sigma_{2u} \frac{\phi(c-\hat{\beta}X)}{1-\Phi(c-\hat{\beta}X)} = \sigma_{2u}\hat{W}_2 \tag{7.22}$$

where, $\phi(\cdot)$and $\Phi(\cdot)$are the probability density and the cumulative density functions, respectively, of the normal distribution. Note that q_1 becomes a part of ßX during estimation and that the parameter c equals q_2-q_1. Substituting $\hat{W}_i$, i = 1, 2, in (7.15) and (7.16) yields the K_2 demand equations

$$\begin{array}{l} \dot{K}_2^- = \gamma_2^- X - \sigma_{1u}\hat{W}_1 + \epsilon_1 \\ \dot{K}_2^+ = \gamma_2^+ X + \sigma_{2u}\hat{W}_2 + \epsilon_2 \end{array} \tag{7.23}$$

6 Through cross parameter restrictions, the parameter M_{22} appears in ßX as well as γX. Theoretically, the parameter M_{22} in ßX should be different for the investment and disinvestment regime. The assumption that M_{22} is the same in both regimes in the first stage estimation of the switching regression model is not unusual (Maddala, 1983).

where ϵ_1 and ϵ_2 are the new disturbance terms[7]. These equations can be estimated jointly in the second stage with the remaining system of netput equations (7.14) and the equation of the remaining net investment demands, $\dot{K}_1$, implied by (7.9).

Price elasticities

In (7.9), C is the matrix of cross terms of prices of netputs and quasi-fixed factors. Given that there are n netputs and 2 quasi-fixed factors, C is an nx2 matrix with elements C_{ij}. Matrix C can be partitioned in two nx1 vectors corresponding to prices of quasi-fixed factors: $C = (C_1, C_2)$. The elements of C_2 differ between the investment and disinvestment and zero investment regime of K_2. This is denoted by C_2^- and C_2^+, respectively. The C matrix with C_2^- or C_2^+ inserted for C_2 is now denoted as C^- and C^+, respectively. The same procedure is followed to obtain a_2^-, B^-, S^-, U^- and a_2^+, B^+, S^+, U^+.

Short term price elasticities indicate the effect of a price change before any adjustment in quasi-fixed factor stocks has taken place. Consequently, quasi-fixed factors are evaluated at their current levels. Short term price elasticities, however, are not independent of the relevant investment regime due to across equation parameter restrictions. Therefore short term responses for the investment, disinvestment and zero-investment regime for K_2 are different. The short term price elasticity of the investment and disinvestment regime are

$$\begin{aligned}\epsilon_{Qv}^{S+} &= \frac{\partial Q}{\partial v}\cdot v(Q^{-1})' \,|\, K=K(t), \dot{K}_2(t) > -\delta K_2 \\ \epsilon_{Qv}^{S-} &= \frac{\partial Q}{\partial v}\cdot v(Q^{-1})' \,|\, K=K(t), \dot{K}_2(t) < -\delta K_2\end{aligned} \qquad (7.24)$$

or

[7] Residuals ϵ_1 and ϵ_2 are heteroscedastic, so equations (7.23) should in principle be estimated by weighted least squares (see Maddala, 1983 : 225).

$$\epsilon_{Qv}^{S+} = \left[\frac{A'}{(\theta' v)} - \frac{(A'v + C^{+'}w)}{(\theta' v)^2}\theta' - \theta\theta'(\theta' v)^{-2}(vw) \begin{bmatrix} A & C^{+} \\ C^{+'} & B^{+} \end{bmatrix} \begin{bmatrix} v \\ w \end{bmatrix} - \theta \frac{(A'v + C^{+'}w)}{(\theta' v)^{-2}} \right] \cdot r \cdot v(Q^{-1})'$$

$$\epsilon_{Qv}^{S-} = \left[\frac{A'}{(\theta' v)} - \frac{(A'v + C^{-'}w)}{(\theta' v)^2}\theta' - \theta\theta'(\theta' v)^{-2}(vw) \begin{bmatrix} A & C^{-} \\ C^{-'} & B^{-} \end{bmatrix} \begin{bmatrix} v \\ w \end{bmatrix} - \theta \frac{(A'v + C^{-'}w)}{(\theta' v)^{-2}} \right] \cdot r \cdot v(Q^{-1})' \tag{7.25}$$

where $Q^{-1'}$ is the vector with the i^{th} element, the inverse of Q_i. If investments in K_2 are zero, the optimal value function may not exist for all values of exogenous parameters and a price elasticity cannot be calculated. However, the expected investment in K_2 can be determined using the parameters of the investment and disinvestment regime and can be regarded as a proxy for the short term response for the zero investment regime. The specification of price elasticities under the zero investment regime must allow for $\dot{K}_2^{+}(t) = \dot{K}_2^{-}(t) = -\delta K_2$ to be imposed in the netput equations corresponding to the disinvestment and investment regime. The expectation is constructed as a weighted mean of the conditional price elasticities of the investment and disinvestment regime

$$E\left[\frac{\partial Q}{\partial v} \cdot v(Q^{-1})' \,|\, K = K(t), \dot{K}_2(t) = -\delta K_2\right] = \tag{7.26}$$
$$P(\dot{K}_2(t) < -\delta K_2 \,|\, \dot{K}_2(t) \neq -\delta K_2) \cdot \epsilon_{Qv|\dot{K}_2^{-}=-\delta K_2}^{S-} + P(\dot{K}_2(t) > -\delta K_2 \,|\, \dot{K}_2(t) \neq -\delta K_2) \cdot \epsilon_{Qv|\dot{K}_2^{+}=-\delta K_2}^{S+}$$

where $P(\dot{K}_2(t) < -\delta K_2(t) \,|\, \dot{K}_2(t) \neq -\delta K_2)$ and $P(\dot{K}_2(t) > -\delta K_2(t) \,|\, \dot{K}_2(t) \neq -\delta K_2)$ are computed using the estimates of the ordered probit model.

In the long run, quasi-fixed factor stocks can adjust to optimal levels. The adjustment for a quasi-fixed factor depends on the regime that applies since a given price change may imply an investment, a disinvestment or no investment at all. Therefore, a first step in determining long term price elasticities is to determine the relevant regime using the results of the ordered probit model. The relevant equation for investments in K_2 is used to determine the long term effects of price changes. For the investment and disinvestment regimes these can be determined by using

$$\epsilon_{Qv}^{L-} = \left\{ \epsilon_{Qv}^{S-} + \epsilon_{QK} \cdot \epsilon_{K^*v} \middle| \ K = K^{*-}, \ \dot{K}_2(t) < -\delta K_2(t) \right\} \tag{7.27}$$

$$\epsilon_{Qv}^{L+} = \left\{ \epsilon_{Qv}^{S+} + \epsilon_{QK} \cdot \epsilon_{K^*v} \middle| \ K = K^{*+}, \ \dot{K}_2(t) > -\delta K_2 \right\} \tag{7.28}$$

Using (7.14) the long term price elasticities are

$$\epsilon_{Qv}^{L-} = \epsilon_{Qv}^{S-} + r \left[P + \theta(G'E'L') \begin{bmatrix} z \\ K \\ t \end{bmatrix} \right] \cdot rN^{-} \left[\frac{C^{-}}{(\theta' v)} - \frac{(B^{-}w + C^{-}v)}{(\theta' v)^{-2}} \theta' \right] \cdot v(Q^{-1})' \tag{7.29}$$

$$\epsilon_{Qv}^{L+} = \epsilon_{Qv}^{S+} + r \left[P + \theta(G'E'L') \begin{bmatrix} z \\ K \\ t \end{bmatrix} \right] \cdot rN^{+} \left[\frac{C^{+}}{(\theta' v)} - \frac{(B^{+}w + C^{+}v)}{(\theta' v)^{-2}} \theta' \right] \cdot v(Q^{-1})' \tag{7.30}$$

The long term price elasticities for the zero investment regime are determined in a way similar to their short term counterparts

$$\begin{aligned} & E\left[\left(\frac{\partial Q}{\partial v} + \frac{\partial Q}{\partial K}\frac{\partial K^*}{\partial v}\right) \cdot v(Q^{-1})' \,\middle|\, K = K^*, \dot{K}_2(t) \neq -\delta K_2 \right] = \\ & P(\dot{K}_2 < -\delta K_2 \,|\, \dot{K}_2 \neq -\delta K_2) \cdot \epsilon_{Qv}^{L-}\Big|_{\dot{K}_2^- = -\delta K_2} + P(\dot{K}_2 > -\delta K_2 \,|\, \dot{K}_2 \neq -\delta K_2) \cdot \epsilon_{Qv}^{L+}\Big|_{\dot{K}_2^+ = -\delta K_2} \end{aligned} \tag{7.31}$$

7.5 Data

Data on specialised cash crop farms covering the period 1971-1992 are obtained from a stratified sample of Dutch farms keeping accounts on behalf of the LEI-DLO farm accounting system. Farms deriving more than 80 percent of their output from marketable crops are the focus of this application. These farms remain in the panel for only five to six years. The data set used for estimation of the ordered probit model contains 4040 observations. Investments in machinery are negative for 95 observations (2.4 percent), zero for 1189 observations (29.4 percent) and positive in 2756 cases (68.2 percent). Only non-zero observations (2851) on investments in machinery are used for the second stage estimation of the system of equations of (7.9), (7.14) and (7.23). Equation (7.9) is estimated for rootcrops area.

Two outputs (rootcrops and other outputs) and three variable inputs (pesticides, N-fertiliser and other inputs) are distinguished. Rootcrops include sugar beet, ware potatoes, seed potatoes and starch potatoes. Other outputs are combined in an aggregate index covering all other marketable crops not accounted for in the previous category, and animal output. Other inputs consist of services, non-nitrogenous fertiliser, seed and planting materials, purchased feed input, livestock costs, energy and other variable inputs.

Quasi fixed inputs are rootcrop-specific area and machinery. Fixed inputs are the total area of rootcrops and other outputs and labour. Areas are measured in hectares; labour is measured in quality-corrected man years, and includes family as well as hired labour. Machinery is measured at constant 1980 prices.

Tornqvist price indexes are calculated for the two outputs and other inputs (prices are obtained from the LEI-DLO/CBS). The price indexes vary over the years but not over the farms, implying differences in the composition of a netput or quality differences are reflected in the quantity (Cox and Wohlgenant, 1986). Implicit quantity indexes are generated as the ratio of value to the price index.

Output prices are not known at the time decisions are made on planting and the use of variable inputs, so expected rather than actual prices are used. Expected output prices are constructed by applying an AR(2) filter to the price of rootcrops and an AR(1) filter to the price of other outputs.

The cost of holding land is calculated as the current value of land assuming a discount rate of 0.04. Land prices are obtained from the LEI-DLO/CBS and are regional prices since large differences in prices prevail between regions. Four regions are distinguished: sea clay, river clay, peat soil and sandy soil. Land prices in the panel vary across regions but not between farms within a region. Machinery costs involve the costs of interest, depreciation and maintenance and are corrected for tax regulations (See Thijssen (1992) for more details).

More information on data used in this chapter can be found in Appendix VI (Table VI.1).

7.6 Results

The threshold model is estimated in two stages. In the first stage, the ordered probit model is estimated (equation (7.12)). Parameter results (see Appendix VI : Table VI.2) are used to calculate the expected error terms (7.18) which are included in the equations for investment and disinvestment in machinery. These equations are estimated in the second stage together with the netput equations and the demand equation for the area of rootcrops using Seemingly Unrelated Regressions. The SUR estimator applied takes into account that the equations in the system have unequal numbers of observations (Judge et al., 1988 P: 463-465). This model contains 92 parameters, including 2 parameters related to the expected error terms in (7.18). The estimated model generates 49 percent of the parameters estimated significant (see Appendix VI : Table VI.3) at the critical 5 percent level. A χ^2 test is used to test the hypothesis that no parameter differences exist for the investment and disinvestment regime of machinery ($\gamma^-_2 = \gamma^+_2$). The null hypothesis of no parameter differences is firmly rejected ($\chi^2_{12,.05} < 121.16$). Table 7.1 presents results of tests on differences between the investment and disinvestment regime for individual pairs of parameters. The critical $\chi^2_{1,.05}$ is 3.84 and it is found that the null hypothesis of no parameter difference between the investment and disinvestment regime is not rejected for the adjustment parameter of machinery (M_{22}) and the parameter relating machinery investments to the quantity of labour (S_{22}).

Table 7.1: Tests of hypotheses for parameter symmetry

Null Hypothesis	Test statistic	Null Hypothesis	Test statistic
$a_{32}^+ = a_{32}^-$	0.86	$C_{42}^+ = C_{42}^-$	0.00
$B_{21}^+ = B_{21}^-$	1.42	$M_{21}^+ = M_{21}^-$	2.28
$B_{22}^+ = B_{22}^-$	0.00	$M_{22}^+ = M_{22}^-$	8.88
$C_{12}^+ = C_{12}^-$	0.57	$S_{21}^+ = S_{21}^-$	1.99
$C_{22}^+ = C_{22}^-$	0.00	$S_{22}^+ = S_{22}^-$	7.98
$C_{32}^+ = C_{32}^-$	0.00	$U_2^+ = U_2^-$	0.00

Short term price elasticities are calculated using (7.25) and are presented in Table 7.2. The own short term price elasticity of other outputs is negative but the size is small and is not inconsistent with the adjustment cost theory (Mortensen, 1973; Caputo 1990). N-fertiliser and other inputs are substitutes for pesticides and the other variable input is a complement for N-fertiliser.

Table 7.2 : Short term price elasticities.

	root-crops	other outputs	pestici-des	N-fertili-ser	other in-puts	land	machi-nery
rootcrops	0.041	0.008	0.014	0.003	-0.038	0.035	-0.063
other outputs	0.012	-0.070	-0.018	-0.033	-0.017	0.030	0.095
pesticides	-0.121	0.091	-0.360	0.149	0.138	-0.008	0.112
N-fertiliser	-0.068	0.519	0.451	-0.086	-0.418	-0.029	-0.369
other inputs	-0.072	0.091	0.049	-0.030	-0.121	0.075	0.007

In order to calculate long term price elasticities, the relevant investment regime for machinery must be determined. Using average values of the data used in this chapter the following probabilities are found: 0.02 for $I_2 < 0$, 0.27 for $I_2 = 0$ and 0.71 for $I_2 > 0$. Therefore, the predicted regime is the (positive) investment regime and the parameters used for calculating the long term price elasticity in (7.28) are a^{+}_{32}, B^{+}_{21}, etc. The own price elasticity of other outputs still has the wrong sign (although the size is not large in absolute terms). Other own price elasticities, including those of the quasi-fixed factors have the expected sign. Other outputs and rootcrops are long term complements. This indicates that rootcrops cannot be grown in the long term without a sufficiently large area of other outputs in the crop rotation. Typically, other outputs are necessary to decrease the pressure of soil diseases in narrow crop rotations with rootcrops. Another way farmers maintain a large area of rootcrops is to use high levels of nematicides. This is reflected by the result that pesticides and rootcrops area are complements.

Machinery is a long term substitute for pesticides and a long term complement for N-fertiliser and other inputs. Farmers need machinery for applying fertiliser and pesticides indicating a complementary relation. In the case of pesticides, farmers also have the option to substitute pesticides for machinery for purposes of mechanical weeding. The results in Table 7.3 suggest the substitution of pesticides for machinery dominates the complementarity effect of applying chemicals and machinery. The complementary relation between the area of rootcrops and N-fertiliser indicates that rootcrops use N-fertiliser more intensively than other outputs.

An increase in the price of rootcrops leads to a small decrease in the area of rootcrops indicating rootcrops area is an inferior input in the production of rootcrops. This may be explained by the fact that the production of rootcrops is relatively more labour demanding than the production of other outputs (PAGV, 1993).

Table 7.3 : Long term price elasticities

	root-crops	other outputs	pesti-cides	N-fertili-ser	other inputs	land	machi-nery
rootcrops	0.037	-0.002	0.015	0.001	-0.027	0.036	-0.060
other outputs	0.043	-0.089	-0.013	-0.039	-0.019	0.038	0.080
pesticides	-0.142	0.104	-0.363	0.153	0.140	-0.014	0.123
N-fertiliser	-0.093	0.543	0.446	-0.080	-0.423	-0.037	-0.358
other inputs	-0.097	0.112	0.045	-0.024	-0.123	0.068	0.019
area rootcrops	-0.337	-0.134	-0.014	-0.002	0.306	-0.011	0.189
machinery	0.781	-0.838	0.165	-0.211	0.227	0.279	-0.365

Tables 7.4 and 7.5 indicate land is a complement for all short and long term variable inputs where labour is a complement for all inputs except for N-fertiliser. Technological progress, as represented by a time trend, has been more beneficial to rootcrops than to other outputs and has also encouraged the use of pesticides more than the uses of N-fertiliser and other inputs. Technological progress in the area of rootcrops and the volume of machinery is very small.

Table 7.4: Short term elasticities of intensity and trends

	land	labour	trend
rootcrops	0.471	0.694	0.042
other outputs	0.837	0.282	0.020
pesticides	0.935	0.228	0.035
N-fertiliser	1.255	-0.353	0.022
other inputs	0.548	0.466	0.009

Table 7.5: Long term elasticities of intensity and trends

	land	labour	trend
rootcrops	0.503	0.702	0.040
other outputs	0.823	0.292	0.018
pesticides	0.943	0.224	0.036
N-fertiliser	1.249	-0.369	0.023
other inputs	0.550	0.455	0.010
area rootcrops	0.960	0.243	-0.007
machinery	0.398	0.765	-0.008

Table 7.6 presents adjustment rates of rootcrops area and machinery for two cases. The first and second columns are generated from the estimates of the threshold model which was estimated on 2851 non-zero observations. The third column presents adjustment rates generated from estimates of the standard (symmetric) adjustment cost model estimated on all 4040 observations. In both the threshold model and the standard adjustment model, the adjustment rate of rootcrops area is small, indicating a 12 and 14 year term of adjustment respectively. Both models also indicate the adjustment of rootcrops area is independent from the adjustment of machinery. Comparison of the adjustment rates of the expanding and contracting regime suggests that machinery adjusts slower in the investment regime (14 years) than in the disinvestment regime (7-8 years). This supports the hypothesis that it is easier for a producer to scale back the operation during hard times than it is to expand during prosperous times. A higher adjustment rate for capital during phases of contractions is also found by Pfann (1996) for the Dutch and

U.K. manufacturing sector. Another finding from Table 7.6 is that machinery does not adjust independently from rootcrops area in the expanding regime while it adjusts independently in the contracting regime. Interestingly, the adjustment rates are effected negligibly by estimating the dual model assuming a standard adjustment cost function.

Table 7.6 : Adjustment rates (t-values in parentheses).

	Threshold model		Standard adjustment cost model
	expanding	contracting	
m_{11}	-0.08 (-16.36)	-0.08 (-16.36)	-0.07 (-19.67)
m_{12}	-0.001 (-1.20)	-0.001 (-1.20)	0.00 (0.05)
m_{21}	0.27 (4.83)	0.01 (0.09)	0.16 (5.20)
m_{22}	-0.07 (-13.64)	-0.13 (-8.12)	-0.07 (-20.31)

The adjustment rate of rootcrops area cannot be compared directly with other models since other studies have not estimated the adjustment rate of the area under a particular crop. The adjustment rate for capital on the other hand has been estimated in many previous studies. Using panel data on Dutch dairy farms Thijssen (1994) finds an adjustment rate for capital of approximately -0.26. Adjustment rates for capital on aggregate data range from -0.15 for the U.S. production agriculture (Luh and Stefanou, 1991) to -0.55 in the Southeastern U.S. production agriculture (Taylor and Monson, 1985). The adjustment rate for machinery estimated in this chapter is small in comparison.

7.7 Simulations

The model developed in the previous sections is used to determine the impacts of asymmetric responses in investments in machinery under three different price scenarios. The first is the baseline simulation holding all prices at their 1992 levels. This represents the scenario when 1992 prices persist throughout the simulation period. The second simulation is a low profit scenario involving a scheme where all output prices are lowered and all input prices are increased by 10 percent each year. The third simulation is a high profit price scenario involving an increase of all output prices and a decrease of all input prices by 10 percent each year.

The simulations are projected over a 5 year period (1992-1997) for all cash crop farms in the sample in 1992 and are presented in Table 7.7. Results of the simulations are aggregated to the sector level using the number of farms in the sector that each farm in the sample represents as weights.

The stock of machinery under the disinvestment and investment regime are calculated using the equations in (7.23). The machinery stock under the zero investment regime in year t equals the machinery stock in year t-1 less depreciation fixed at 10 percent. The expected machinery stock is calculated from the stocks and probabilities of each regime. Investment in machinery in year t is conditioned on the expected machinery stock in year t. The machinery stock in the initial year, 1992, is the same in all simulations.

In the base simulation, the probability of each regime remains fairly constant over time. In the low profit simulation, the probabilities of the disinvestment and zero investment regime increase. Farms must decrease the size of the farm operation, but lower the capital stock more by letting assets depreciate than by actively disinvesting. In the high profit simulation there are virtually no more firms disinvesting whereas the probability of zero investment has deceased by 62 percent. The expected machinery stock increases by more than 15 percent indicating that farms increase the size of the farm operation in this simulation. However, the increase in the farm size is hampered by inactivity, also under very favourable price conditions.

Table 7.7 : Results of simulations : Index numbers of volume of machinery by regime and expected volume (1992=100). Probability by regime in parentheses.

Regime	Time				
	1	2	3	4	5
Baseline simulation					
disinvestment	80.92 (0.01)	80.19 (0.01)	79.65 (0.01)	79.29 (0.01)	79.09 (0.01)
zero investment	90 (0.24)	89.57 (0.23)	89.34 (0.23)	89.29 (0.22)	89.41 (0.21)
investment	103.38 (0.75)	103.05 (0.76)	102.93 (0.76)	102.99 (0.77)	103.24 (0.78)
expected volume	99.52	99.26	99.21	99.35	99.67
Low profit simulation					
disinvestment	80.92 (0.02)	80.82 (0.02)	79.94 (0.03)	78.44 (0.04)	76.48 (0.05)
zero investment	90 (0.27)	91.32 (0.30)	91.06 (0.33)	89.56 (0.36)	87.14 (0.39)
investment	103.38 (0.71)	102.29 (0.68)	100.53 (0.64)	98.29 (0.60)	95.75 (0.56)
expected volume	99.52	98.15	96.06	93.42	90.42
High profit simulation					
disinvestment	80.92 (0.01)	79.54 (0.01)	79.43 (0.00)	80.71 (0.00)	83.62 (0.00)
zero investment	90 (0.21)	89.57 (0.17)	90.50 (0.14)	92.95 (0.11)	97.18 (0.08)
investment	103.38 (0.78)	104.01 (0.83)	106.36 (0.86)	110.74 (0.89)	117.68 (0.92)
expected volume	99.52	100.56	103.27	107.98	115.25

7.8 Discussion and conclusions

This chapter provides a framework for consistent estimation of a dynamic dual model for the case where data reveal zero and non-zero investments. The threshold model developed maintains investments are zero if the shadow value of machinery is between a lower and an upper threshold. Separate equations are estimated for the investment and the disinvestment regime. A significant difference is found between the parameters of the investment and disinvestment equations. The test for differences in individual parameters indicates a significant difference for two of the twelve parameters. Short- and long-term price elasticities conditioned on a regime are derived.

The adjustment rates for machinery reveal adjustment terms of 7-8 years for disinvestments and 14 years for investments. The difference in the adjustment parameters implies it is easier for the producer to scale back rather than to expand the size of the operation. The own adjustment rate for machinery that is found, assuming a standard adjustment cost function, is equal to the adjustment rate of the investment regime. However, a standard adjustment cost function conceals differential behavior since the threshold model allows farmers to exhibit different adjustment rates for different regimes.

The simulations performed with the threshold model have demonstrated farmers' differential reactions to price changes. Under unfavourable price conditions, active disinvestment is less attractive as a means of contracting than passive disinvestment through depreciation.

Results in this chapter show that a significant difference exists between the contracting and expanding regime for investments in machinery. Hence they question for machinery the validity the assumptions in the standard adjustment cost model that ensure symmetric adjustment. In future research, asymmetric adjustment may also be tested for other quasi-fixed factors.

Chapter 8

Concluding comments and future research

8.1 Introduction

This thesis has presented several applications of micro economic theory on panel data of Dutch arable farms. Models that were presented in chapters 3-5 were used for analysing policy changes. The focus in chapters 2 and 6-7 was on the methodology of testing among functional forms, modelling simultaneous production/input and area allocation decisions under price uncertainty and modelling investment behaviour on firm level data, respectively. Conclusions were given at the end of the corresponding chapters. This chapter provides a general discussion of model assumptions and results and gives prospects for future research.

8.2 Concluding Comments

Functional forms

Chapter 2 shows that different functional forms give different results (e.g. price elasticities) on the data set that was used in this thesis. This is the central motivation for paying explicit attention to the choice of functional forms. The main criteria for selecting among functional forms in Chapter 2 is the performance on a test against a linear Generalised Box-Cox that includes three flexible linear functional forms as nested hypotheses. All functional forms were rejected against the linear Generalised Box-Cox. However, the performance of the Normalised Quadratic was less unfavourable on this test than that of the other functional forms, and it also performed better on criteria as regularity conditions and parameter significance.

Although the results of the tests in Chapter 2 were important for motivating the choice of the Normalised Quadratic in chapters 3-6, other criteria also played a role there. Its computational ease and simplicity was an important criteria in chapters 3-6 and the possibility to check and/or impose curvature conditions globally played a role in chapters 3-5. The Normalised Quadratic was conceptually infeasible in chapter 7, since the equation of the numeraire input could not be derived in the framework that was adopted here. The Symmetric Normalised Quadratic that was used instead, avoids the need to derive the equation of the numeraire netput, although it should be noted that the Generalised Leontief has the same feature (see Howard and Shumway, 1988). However, the Symmetric Normalised Quadratic was not used before in a dynamic model and employing this functional form provides a new element in the literature.

It is important to note that the tests of different functional forms in chapter 2 were performed within a static framework, assuming price certainty (or risk neutrality) and using a specific separability structure with one output and two variable inputs. These conditions are similar to those in Chapter 3, but more different from those in Chapters 4-7. Therefore, the weight that can be attached to the test results in Chapter 2 for selecting functional forms is larger in Chapter 3 than in the remaining chapters.

Separability

Researchers are often faced with the need to aggregate inputs and outputs in composite indexes of inputs and outputs. One reason is that regularity conditions often fail to hold when distinguishing a large number of inputs and outputs; convexity in prices also failed to hold in this thesis for all models that distinguish multiple inputs and outputs (Chapters 4-7)[1]. An other reason for aggregating inputs and output to broad composite indexes applies when farm level data are used. That is, the occurrence of observations reporting zero levels of inputs and outputs may be substantial when maintaining a very low level of aggregation. A sufficient condition for aggregating inputs and outputs in composite input and output categories is weak separability.

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[1] Note that convexity in prices was *imposed* during estimation in the model of chapters 4-5.

Criteria that were used for aggregating inputs and outputs in this thesis are (1) the technical constraints of arable production and (2) the aim of the model i.e. analysing policy changes. Technical constraints played a role in defining potatoes and sugar beet in one index (rootcrops), since both crops are faced with production constraints caused by quotas (sugar beets) and/or crop rotation diseases. The aim of using the model for policy analysis was important in distinguishing CO crops, pesticides and N-fertiliser in chapters 3-5.

The sufficient condition of weak separability was not tested empirically in either of the chapters of thesis, because a test on weak separability does not exist (except for a more restrictive test on homothetic separability (see Pope and Hallam, 1988)).

Price elasticities

Several estimates of price elasticities have been presented in Chapters 2-7. Table 8.1 gives an overview of model structure, estimators applied and estimates of own price elasticities of outputs and variable inputs.

Own price elasticities become larger (in absolute terms) if more inputs become variable, which is the Le Chatelier-Samuelson effect (Chambers, 1988 : 275). This can be seen by comparing own price elasticities in Chapters 2-3, with those in Chapters 4-5. In Chapters 4-5 there is one additional variable input (CO crops area) and own price elasticities are all larger (in absolute terms) than the models based on the same functional form in Chapters 2-3.

Own price elasticities also increase if an estimator is applied that uses both cross sectional and time series variation of the data (like in Chapters 6 and 7). The fixed effects estimator that is used in chapters 2-5 excludes the impact of farm-specific variables (e.g. soil quality) on the size of farmers' responses (since it uses only time-series or "within groups" variation) and is therefore likely to generate smaller (in absolute terms) own price elasticities.

Table 8.1 : Model structure, estimators applied and estimates of price elasticities in Chapters 2-7.

Chapter	Model[a]	#Outputs	#Var. inputs	Own output price elasticities	Own input price elasticities	Estimator[b]	Func. form[c]	page
2	S-T/C	1	3[f]	0.05	-0.20 - -0.24	FE/ITSUR	NQ	26
2	S-T/C	1	3[f]	0.10	-0.47 - -0.55	FE/ITSUR	SNQ	26
2	S-T/C	1	3[f]	0.02	-0.15 - -0.46	FE/ITSUR	GL	26
3	S-T/C	1	3[f]	0.08	-0.12 - -0.43	FE/ITSUR	NQ	40
4/5	S-T/C	3[d]	4[g]	0.14 - 0.90	-0.25 - -0.48	FE/3SLS	NQ	135
6	S-T/U	3[d]	4[g]	0.52 - 3.72	-0.08 - -1.27	FIML	NQ	89
7	L-T/C	2[e]	5[h]	-0.09 - 0.04	-0.08 - -0.36	SUR	SNQ	108

a) S-T = Short-Term, L-T = Long Term, C = price certainty, U = price uncertainty
b) FE = Fixed effect estimator, ITSUR = Iterative Seemingly Unrelated Regression, 3SLS = Three Stage Least Squares, FIML = Full Information Maximum Likelihood.
c) NQ = Normalised Quadratic, SNQ = Symmetric Normalised Quadratic, GL = Generalised Leontief.
d) Cereals/Oilseeds, Rootcrops and Other Outputs
e) Rootcrops and Other Outputs
f) Pesticides, N-fertiliser and Other variable Inputs
g) Pesticides, N-fertiliser, Other variable Inputs and CO crops area
h) Pesticides, N-fertiliser, Other variable Inputs, Rootcrops crops area and Machinery

Incorporating policy measures in micro economic models

A general characteristic of Chapters 3-5 is that policy measures were explicitly incorporated in micro economic models that were estimated on data from a period where the policy measure was not yet implemented. These chapters therefore combine historical information on the production technology with policy parameters that are known at the time of the introduction (area premium, target reduction levels of detrimental inputs, accounting relationships for mineral surpluses etc.), to yield information on the effects of policy measures or combinations of policy measures.

Heterogenous reactions

The availability of panel data for this thesis allowed for an examination of the effects of policy changes or changes in exogenous variables at the level of the individual farm. Within the sector reactions of farms or groups of farms may be quite different.

This thesis has examined two different causes for the occurrence of heterogeneous reactions within the sector.

The first cause for heterogenous reaction within the sector is dealt with in chapters 4-5. Policy changes that were modelled there require a farm-specific approach, since the way the measures work out at the farm level is conditional on variables that are endogenous to the farmer (e.g. area of CO crops and N-surplus). As a result of this, it may be expected that reactions of different farms on policy changes are quite different. To account for this, the effects of the policy changes are determined for individual farms. For presentation purposes, results are aggregated for different farm classes and for the sector. To a certain extent, differences in reactions that are found between farms in Chapters 4-5, are also caused by differences in technology through farm-specific and regional dummies.

An other cause for heterogenous reactions, that is dealt with in Chapter 7, are asymmetric adjustment costs for machinery. Chapter 7 shows that, by allowing for asymmetric adjustment costs, farms can either invest, disinvest or remain inactive. Farmers can also exhibit differential behaviour for investments and disinvestments.

Price uncertainty

The effects of price uncertainty on Dutch arable farmers' behaviour were investigated in Chapter 6. Dutch arable farmers are found to exhibit the risk configuration Increasing Absolute Risk Aversion/Constant Relative Risk Aversion. The evidence for risk aversion that is found in Chapter 6 has implications for the results that are found in Chapters 4-5, since the model that is used in these chapters assumes that farmers are risk neutral and/or do not face price uncertainty. The increase in variability of cereals prices after the 1992 CAP reform conceivably leads to an increase in price uncertainty and implies that risk averse farmers will make a trade off between risky income from cereals and oilseeds production and certain income from area and set aside premiums. Since risk averse farmers attach a higher value to save income than to risky income, under increased price uncertainty, they have a larger area of CO crops with a lower intensity of production and are more likely to participate in the set-aside arrangement than risk neutral farmers.

Short versus Long term effects

Effects of policy measures that are presented in chapters 3-5 are short term effects, i.e. they are conditional on quantities of fixed inputs and the state of the technology. Of course it is conceivable that the policy measures affect quantities of fixed input and the producers' technology in the long term. Chapter 7 shows that the volume of machinery and the area of rootcrops are responsive to changes in exogenous variables. Theoretically therefore, the long term effects of the policy changes in Chapters 3-5 are larger than the effects that are reported. A further increase of the effects will occur if adjustments in the volumes of land and labour, technological change and entry/exit behaviour are accounted for.

8.3 Future Research

This thesis has dealt with a selection of research questions that relate to arable farming. Chapter 1 mentions a few issues that are not covered by this thesis, and that are still open for future research : the use of natural resources (e.g. water use, genetic variability), nature/landscape production and CO_2 emission. The effect of a reduction of pesticides use on yield variability and soil fertility is an other issue that is relevant regarding the policy measures that are proposed for arable farming. Although the problem of the mineral surplus is not irrelevant to arable farming, it is certainly more urgent in other sectors, especially in dairy farming and intensive livestock farming. The methodology for analysing the effects of mineral surplus policy, that is proposed in chapter 5 can also be applied to these sectors, although more variables (number of animals, manure production and application) are needed there.

Future research should also aim at making achievements in explaining investments in quasi-fixed inputs that are closely related to entry-exit decisions. Land and labour are examples of such variables in arable farming. Neoclassical theory assumes that firms are maximising the discounted value of future profits and assumes that adjustment costs cause sluggishness of investments. Pindyck and Dixit (1994) however show that uncertainty over future profits also plays an important role in entry-exit/investment decisions. Long term decisions may however also be affected by other objectives of the firm such as savings and excellent technical results, or by household characteristics such as the availability of a successor and age/education of the farmer.

An area that can also be explored is the effect of an increase in price variability on producers behaviour and the role that hedging can play in reducing price risk. Given the role for pesticides in reducing output risk and the fact that policy is aiming at reducing pesticides use, the simultaneous effects of output and price risk are a very relevant and interesting area for future research.

Similarly, the frequently perceived role for new technologies in solving environmental problems requires a modification for modelling technological change. The models that were developed in this thesis have assumed that technological change follows a time trend. However, when the use of detrimental inputs become subject to binding constraints, technological change will be biased towards relieving their severeness, i.e. technological change becomes endogenous.

Finally, future research may involve the use of relatively new methods, such as nonparametric or semi-parametric estimation techniques (Härdle, 1989) in combination with panel data estimation methods (Horowitz and Markatou, 1996). Error-correction methods for panel data (Breitung, 1994; Lindquist, 1994) are an alternative way of analysing long term relationships. A new and promising area is the estimation of farm-specific profit functions using maximum Entropy-based methods (Golan et al., 1996; Paris and Howitt, 1996).

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Appendix I : Tables used in Chapter 2.

Table I.1 : Mean and standard deviation of variables in Chapter 2.

Variable	Dimension/base year	Symbol	period : 1970-88 observations : 3249 number of farms : 733	
			mean	standard deviation
Price indexes				
Output	base year 1980	v_1	0.94	0.20
Pesticides	base year 1980	v_2	1.00	0.16
Other inputs	base year 1980	v_3	0.93	0.22
Quantities				
Output	prices of 1980	q_1	299648	219578
Pesticides	prices of 1980	q_2	-19822	16428
Other inputs	prices of 1980	q_3	-96283	61588
land	ares	c_1	5289	3686
labour	manyears * 10	c_2	17.18	8.99
capital	inventory value of machinery and livestock (1980 prices)	c_3	138214	99999
technology	trend (1970=1)	c_4	10.90	4.81

Table I.2 : Derivation of price elasticities and elasticities of intensity from the parameters of the profit function

FFF\ ϵ	ϵ_{ii}	ϵ_{ij}	ϵ_{ic_j}
GL	$-\frac{1}{q_i}\left[0.5\,\alpha_i(v_i^*)^{0.5}+\alpha_{ij}\frac{(v_j^*)^{0.5}}{(v_i^*)^{0.5}}+\sum_{j=1}^{3}\gamma_{ij}\frac{c_j^{0.5}}{(v_i^*)^{0.5}}\right]$	$\frac{\alpha_{ij}}{q_i}\cdot\frac{(v_j^*)^{0.5}}{(v_i^*)^{0.5}}$	$\gamma_{ij}(\frac{c_j}{v_i^*})^{0.5}\frac{1}{q_i}$
NQ	$\alpha_{ii}\cdot\frac{v_i^*}{q_i}$	$\alpha_{ij}\cdot\frac{v_j^*}{q_i}$	$\gamma_{ij}\cdot\frac{c_j}{q_i}$
SNQ[1]	$\frac{\alpha_{ii}}{\sum_{k=1}^{3}\theta_k v_k}\cdot\frac{v_i}{q_i}$	$\frac{\alpha_{ij}}{\sum_{k=1}^{3}\theta_k v_k}\cdot\frac{v_j}{q_i}$	$(\theta_i(\sum_{k=1}^{3}\beta_{kj}c_k)+\gamma_{ij})\cdot\frac{c_j}{q_i}$

1) This is the expression for the price elasticity at the sample mean. The expression at other points involves additional terms.

ϵ_{ij} = price elasticity netput i with respect to price j.

ϵ_{ic_j} = elasticity of intensity of netput i with respect to fixed input j

Appendix II : Tables used in Chapter 3.

Table II.1 : Mean and standard deviation of variables used in Chapter 3.

Variable	Dimension/base year	Symbol	period : 1970-'88 observations : 3258 number of farms : 733	
			mean	standard deviation
Price indexes				
Output	base year 1980	v_1	1.06	0.26
Pesticides	base year 1980	v_2	1.11	0.16
N-fertilizer	base year 1980	v_3	0.96	0.10
Quantities				
Output	prices of 1980	q_1	299504	220279
Pesticides	prices of 1980	q_2	-19802	16413
N-fertilizer	prices of 1980	q_3	-8090	7687
other inputs	prices of 1980	q_4	-88158	557300
land	ares	c_1	5284	3682
labour	manyears * 10	c_2	17.15	8.99
capital	inventory value of machinery and livestock (prices of 1980)	c_3	138031	99962
other				
technology	trend (1970=1)	t	11.91	4.80
weather	average weather=1	w	1.00	0.06

Table II.2 : Results of estimation

parameter	estimate	standard error	parameter	estimate	standard error
α_1	-328874.14	20609.01	ρ_{13}	0.30	0.03
α_2	-4475.91	14679.78	ρ_{21}	-2.94	0.18
α_3	1662.59	16304.74	ρ_{22}	-95.02	36.25
β_1	-23.87	5.64	ρ_{23}	-0.02	3E-3
β_2	7300.49	2057.29	ρ_{31}	-1.29	0.14
β_3	0.20	0.19	ρ_{32}	-15.29	29.60
τ_t	4662.13	1890.69	ρ_{33}	-5E-3	3E-3
ω_w	-1742611.08	461972.59	τ_{v1}	7324.55	608.14
α_{11}	23093.12	6808.41	τ_{v2}	-996.65	69.77
α_{12}	-1389.45	539.66	τ_{v3}	-84.92	56.88
α_{13}	-702.46	447.08	ω_{v1}	252743.73	18360.47
α_{22}	2105.39	1471.98	ω_{v2}	6651.38	1602.97
α_{23}	416.31	993.78	ω_{v3}	50.22	1328.41
α_{33}	3620.95	1372.39	τ_{z1}	0.27	0.15
β_{11}	13E-5	2E-4	τ_{z2}	-62.28	49.07
β_{12}	10E-3	0.08	τ_{z3}	-3E-3	5E-3
β_{13}	7E-6	7E-6	ω_{z1}	7.86	4.81
β_{22}	42.55	30.25	ω_{z2}	-7233.71	1931.00
β_{23}	-7E-3	2E-3	ω_{z3}	-0.31	0.17
β_{33}	5E-7	3E-7	τ_{tt}	-306.31	13.25
ρ_{11}	30.49	1.21	ω_{ww}	1842471.01	47052.89
ρ_{12}	4872.02	342.05			

Appendix III : Tables used in Chapter 4.

Table III.1 Average calculated values of variables in 1992.

	netput quantities[1]						fixed inputs					profit[1]
farm class	CO crops	other outputs	root-crops	pesti-cides	N-fer-tiliser	other inputs	Area CO -crops[2]	Area other outputs[2]	Area root-crops[2]	Labour[3]	Capital[1]	
1	10.43	295.96	121.32	-15.18	-4.75	-80.12	2.83	17.83	10.85	21.10	231.43	185.92
2	47.90	42.47	113.16	-12.66	-6.51	-36.01	13.99	8.67	17.36	12.27	134.40	118.12
3	125.20	111.67	401.70	-33.22	-13.00	-91.86	39.60	20.17	41.71	23.38	500.45	525.69
4	13.26	78.54	239.17	-25.50	-7.96	-66.55	3.93	11.39	32.44	14.22	235.52	143.81
5	41.09	26.69	303.15	-28.01	-13.81	-80.10	15.59	4.24	44.24	14.72	244.94	183.73
6	56.93	62.63	412.71	-50.95	-18.71	-88.31	20.09	13.57	57.70	17.30	429.12	267.56
7	32.94	100.31	132.72	-14.64	-4.09	-52.49	7.94	11.39	11.69	11.78	192.31	90.94
8	59.08	90.93	160.53	-18.06	-6.54	-57.83	14.90	15.41	16.74	13.09	280.13	98.53
9	126.62	116.90	263.75	-31.36	-12.45	-81.50	30.83	17.05	26.89	16.26	413.16	222.99
10	24.57	91.65	271.92	-21.33	-3.77	-71.70	6.06	9.08	22.05	14.31	279.89	166.34
11	67.21	97.31	361.84	-35.07	-9.58	-104.59	16.35	7.92	33.30	15.57	329.15	195.12
12	114.83	102.07	543.81	-47.91	-13.01	-122.87	27.15	9.69	46.07	24.84	635.15	346.85
sector	50.26	108.41	225.41	-23.14	-7.15	-70.17	12.59	12.72	22.70	14.83	287.88	158.80

1) 1980 guilders x 10^3
2) hectares
3) manyears x 10

Table III.2 Actual values of endogenous variables in 1992[1].

farm class	CO - crops	other outputs	root-crops	pesti-cides	N-fer-tiliser	o'her 'nputs	Area CO crops	Area other outputs	profit
1	8.97	356.54	117.19	-13.37	-3.93	-83.43	2.85	17.81	215.68
2	40.33	46.04	136.11	-11.23	-5.44	-38.73	11.18	11.48	105.67
3	124.84	114.56	518.73	-37.90	-18.05	-109.18	40.68	19.09	391.42
4	8.05	85.91	288.38	-24.03	-6.43	-70.55	2.62	12.67	180.14
5	36.91	23.52	357.23	-38.97	-11.69	-89.10	15.51	4.31	194.54
6	50.46	78.76	518.63	-50.71	-14.61	-95.66	16.76	16.90	322.49
7	29.46	114.79	140.82	-14.24	-3.71	-58.05	6.99	12.57	123.13
8	57.40	97.11	174.45	-17.14	-5.68	-61.01	14.21	16.10	149.33
9	128.61	125.94	291.43	-30.69	-10.49	-87.40	29.28	18.61	260.46
10	20.28	98.94	293.50	-20.94	-2.87	-73.89	5.25	9.89	202.49
11	66.75	115.29	416.04	-33.25	-9.05	-100.55	15.65	8.62	293.94
12	118.88	140.78	584.38	-47.23	-10.15	-141.95	25.29	11.55	416.95
sector	47.91	122.24	250.41	-22.34	-6.03	-74.59	11.57	13.75	197.70

1) See Table III.1 for dimensions

Table III.3 Price elasticities in 1992 (weighted average).

	CO crops	other outputs	rootcrops	pesticides	N-fertiliser	other inputs
CO crops	0.90	-0.44	-0.07	-0.12	-0.06	-0.21
other outputs	-0.22	0.14	-0.07	0.01	0.00	0.14
rootcrops	-0.01	-0.03	0.24	0.00	0.03	-0.23
pesticides	0.17	-0.03	0.00	-0.48	0.02	0.32
N-fertiliser	0.38	-0.06	-0.09	0.09	-0.25	-0.07
other inputs	-0.24	0.03	0.51	0.14	0.01	-0.45
area CO crops	1.01	-0.51	-0.11	-0.11	-0.05	-0.23
area other outputs	-1.03	0.51	0.11	0.11	0.05	0.25

Table III.4 Elasticities of intensity in 1992 (weighted average).

	area CO crops and other outputs	area rootcrops	Labour	Capital
CO crops	0.62	0.36	0.01	-0.23
other outputs	0.45	-0.24	0.21	0.40
rootcrops	-0.12	0.66	0.14	0.12
pesticides	0.17	0.45	0.08	0.27
N-fertiliser	0.50	0.62	-0.07	-0.06
other inputs	-0.04	0.28	-0.07	0.59
area CO crops	0.78	0.39	0.04	-0.33
area other outputs	1.22	-0.38	-0.04	0.33

Table III.5 Shadow prices of fixed inputs in 1992.

variable	units	value
area CO crops and other outputs	guilders/hectare	893
area rootcrops	guilders/hectare	3166
labour	guilders/man year	28970
capital	percentage	0.028
trend	guilders/year	10250

Table III.6 Number of farms in new situation, that participate in set-aside (percentage of total number in every farm class in parentheses).

Classification based on new situation	base simulation	25% reduction in area premiums	24% price reduction for CO crops
3	49 (100.0)	35 (70.8)	49 (100.0)
6	39 (100.0)	39 (100.0)	39 (35.2)
8	720 (100.0)	570 (100.0)	711 (100.0)
9	1390 (100.0)	1330 (100.0)	1543 (100.0)
11	158 (91.7)	210 (90.7)	59 (100.0)
12	318 (100.0)	259 (100.0)	490 (100.0)
Total	2674 (99.5)	2443 (98.6)	2891 (97.6)

Table III.7 Effects[1] of the new CO regime with a 25% reduction in area premiums (upper part) and with a 24% price reduction for CO crops (lower part).

	netput quantities						miscellaneous			
farm class	CO crops	other outputs	rootcrops	pesticides	N-fertiliser	other inputs	Area CO crops[2]	Area of other outputs	% of total area set-aside	profit
The new CO regime with a 25% reduction in area premiums										
1	-78.80	1.40	0.28	-5.56	-12.16	-2.43	-81.16	12.86	0.00	-0.43
2	-17.16	9.76	0.30	-6.67	-8.87	-14.54	-16.39	26.46	0.00	-4.32
3	-9.76	1.14	0.61	-3.76	-7.16	-15.58	-8.85	7.75	1.91	-3.57
4	-62.00	5.28	0.14	-3.31	-7.26	-2.20	-58.39	20.14	0.00	-0.72
5	-20.00	15.53	0.11	-3.01	-4.18	-5.73	-14.72	54.18	0.00	-1.62
6	-16.18	3.74	0.30	-1.91	-3.74	-4.94	-12.98	12.57	0.99	-1.78
7	-16.14	2.56	0.05	-4.41	-10.64	7.46	-18.42	12.60	0.00	-3.36
8	-11.20	1.16	0.60	-4.38	-8.69	5.53	-12.50	6.56	1.81	-5.30
9	-8.49	-3.69	1.51	-4.05	-8.10	2.68	-10.19	-3.72	5.05	-6.24
10	-21.64	2.80	0.02	-3.03	-11.55	5.91	-24.13	16.11	0.00	-1.29
11	-9.82	-0.58	0.42	-2.38	-6.45	1.81	-11.50	5.15	2.56	-2.97
12	-9.50	-2.42	0.62	-2.58	-7.39	2.00	-11.65	0.64	3.74	-3.74
sector	-14.63	1.24	0.47	-3.65	-8.50	2.75	-16.49	9.29	1.86	-3.16
The new CO regime with a 24% price reduction for CO crops										
1	-12.95	0.17	-0.15	-1.93	-4.01	-0.54	-12.22	1.94	0.00	-0.13
2	-2.82	1.18	-0.16	-2.31	-2.93	-2.58	-2.47	3.98	0.00	-0.59
3	-7.48	-7.35	1.27	-3.55	-7.62	0.86	-7.08	-10.98	4.95	-1.63
4	-10.19	0.64	-0.08	-1.15	-2.39	-0.54	-8.79	3.03	0.00	-0.10
5	-3.29	1.87	-0.06	-1.05	-1.38	-1.04	-2.22	8.16	0.00	0.64
6	-6.66	-1.18	0.23	-1.03	-2.08	-2.01	-5.35	0.66	1.08	0.32
7	7.20	-1.79	-0.33	-0.32	-0.41	-3.97	9.02	-7.04	0.33	0.39
8	-1.74	-3.72	0.67	-2.03	-4.44	-1.15	-2.01	-7.29	3.03	0.91
9	-2.87	-7.54	1.40	-2.30	-5.07	1.22	-3.66	-17.14	5.42	-0.48
10	9.94	-1.90	-0.18	-0.18	-0.28	-3.13	12.17	-8.85	0.18	0.22
11	-1.69	-4.07	0.36	-1.11	-3.29	-1.23	-2.07	-16.75	2.89	0.54
12	-3.01	-7.47	0.60	-1.41	-4.48	0.86	-3.91	-25.75	4.29	-0.46
sector	-0.72	-2.65	-0.31	-1.29	-3.22	-1.27	-0.77	-7.77	2.26	0.00

1: Percentage changes in quantities of netputs, area of CO crops and other outputs, land set-aside and profit compared to the calculated 1992 level

2: Excluding area set-aside

Appendix IV Tables used in Chapter 5.

Table IV.1 Average values of endogenous variables by farm in base simulation.

farm class	CO crops[1]	other outputs[1]	root-crops[1]	pesticides[1]	N-fer-tiliser[1]	other inputs[1]	Area CO -crops[2]	Area set-aside in % total area	Area other outputs[2]	N-surplus threshold 125 kg/ha	profit[1]
1	12.96	163.96	225.69	-23.37	-5.39 -5.29	-76.35	3.96	0.32	15.80	53.55	188.48
2	50.08	95.47	227.73	-21.28	-10.59	-71.23	12.11	2.30	13.11	50.87	141.57
3	16.07	93.77	210.90	-23.66	-11.87	-60.87	5.36	0.16	12.19	170.59	141.53
4	84.41	115.89	234.38	-26.78	-6.72	-71.77	20.04	4.84	10.35	161.53	195.41
sector	45.45	108.11	226.52	-22.56		-70.97	11.22	2.17	13.05	80.04	155.51

1) 1980 guilders x 10^3
2) hectares

Table IV.2 : Results of simulation : no set-aside / no levy

farm class	CO crops	other outputs	rootcrops	pesticides	N-fer-tiliser	other inputs	Area CO - crops	Area set-aside in % total area[1]	Area other outputs	N-surplus threshold 125 kg/ha[2]	profit
1	1.8	0.2	-0.1	0.1	0.4	0.2	1.8	0	0.5	0.3	0.1
2	4.2	1.8	-0.5	1.0	3.6	-0.5	5.3	0	3.4	2.5	0.3
3	0.7	0.2	-0.0	0.1	0.1	0.0	0.6	0	0.4	0.2	0.0
4	5.5	3.8	-1.2	1.8	3.7	-0.6	7.0	0	12.0	4.6	1.1
sector	4.3	1.5	-0.5	0.9	2.7	-0.3	5.3	0	3.5	2.2	0.4

1: Absolute level
2: Absolute change per hectare

Appendix V : Tables used in Chapter 6.

Table V.1 : Description of data and variability

Variable	Dimension/base year	Symbol	period : 1974-'92 observations : 3571 mean	standard deviation
Price indexes				
CO crops	base year 1980	v_1	0.95	0.18
Other Outputs	base year 1980	v_2	0.91	0.25
Rootcrops	base year 1980	v_3	0.95	0.22
Pesticides	base year 1980	v_4	1.03	0.07
N-fertiliser	base year 1980	v_5	0.87	0.14
Income				
Mean income	1000 guilders of 1980	M	182.40	57.16
Exogenous income	1000 guilders of 1980	E	14.60	17.10
Profit	1000 guilders of 1980	$p^TQ-C(w,Q)$	167.79	130.93
Quantities				
CO crops	1000 guilders of 1980	q_1	42.91	49.13
Other Outputs	1000 guilders of 1980	q_2	69.19	82.09
Rootcrops	1000 guilders of 1980	q_3	192.97	160.74
Pesticides	1000 guilders of 1980	x_1	20.22	15.59
N-fertiliser	1000 guilders of 1980	x_2	7.36	6.06
Other inputs	1000 guilders of 1980	x_3	80.50	46.85
CO crops area	Hectares	z_1	12.18	12.64
Other outp. area	Hectares	z_2	23.77	18.37
Rootcrops area	Hectares	z_3	23.02	15.43
Labour	man years*10	z_4	15.16	6.78
Capital	1000 guilders of 1980	z_5	136.65	99.34
Trend	1973=0	z_6	10.34	5.47
region	high productivity=1	z_7	0.68	0.47

Table V.2 : Parameter estimates and t-values.

parameter	value	t-value	parameter	value	t-value
$\alpha0$	33.861	5.15	$\lambda22$	0.002	44.66
$\alpha1$	15.184	3.85	$\lambda23$	-0.000	-8.56
$\alpha2$	15.494	3.07	$\lambda33$	0.001	56.91
$\beta1$	-0.990	-2.49	$\gamma11$	-0.447	-1.91
$\beta2$	-2.913	-10.34	$\gamma12$	-0.024	-0.14
$\beta3$	0.174	1.02	$\gamma13$	0.493	20.09
$\beta4$	-3.152	-8.06	$\gamma14$	-0.251	-3.20
$\beta5$	-0.329	-10.40	$\gamma15$	-0.003	-0.39
$\beta6$	-2.935	-5.33	$\gamma16$	-0.144	-2.62
$\beta7$	-16.689	-4.85	$\gamma17$	-0.080	-0.18
$\lambda1$	1.123	14.65	$\gamma21$	-1.002	-5.29
$\lambda2$	1.296	27.87	$\gamma22$	0.939	6.81
$\lambda3$	0.490	41.97	$\gamma23$	0.211	8.59
$\alpha11$	-9.806	-4.14	$\gamma24$	0.277	4.19
$\alpha12$	-3.648	-1.51	$\gamma25$	0.041	5.90
$\alpha22$	-11.907	-3.17	$\gamma26$	-0.054	-0.71
$\beta11$	-0.040	-4.87	$\gamma27$	-3.362	-7.02
$\beta12$	0.142	31.48	$\eta11$	0.205	4.15
$\beta13$	-0.014	-4.84	$\eta12$	0.062	1.93
$\beta14$	0.048	7.96	$\eta13$	0.029	16.65
$\beta15$	0.009	21.44	$\eta21$	0.228	6.00
$\beta16$	0.075	7.59	$\eta22$	-0.151	-5.80
$\beta17$	-0.116	-1.14	$\eta23$	-0.019	-9.18
ß22	-0.008	3.95	$\mu11$	-0.008	-4.01
$\beta23$	0.002	1.03	$\mu12$	-0.040	-33.4
$\beta24$	-0.016	-4.02	$\mu13$	0.006	8.71
$\beta25$	0.002	7.35	$\mu14$	-0.014	-11.03
$\beta26$	0.074	11.82	$\mu15$	-0.002	-22.21
$\beta27$	0.062	0.78	$\mu16$	-0.044	-22.28
$\beta33$	0.007	2.93	$\mu18$	-0.026	-1.49
$\beta34$	0.004	0.70	$\mu21$	-0.030	-37.17
$\beta35$	0.0004	0.93	$\mu22$	-0.002	-8.91
$\beta36$	0.015	1.85	$\mu23$	0.006	32.11
$\beta37$	0.802	8.13	$\mu24$	-0.007	-20.41
$\beta44$	0.021	1.36	$\mu25$	-0.001	-19.61
$\beta45$	0.006	5.58	$\mu26$	-0.036	-35.82
$\beta46$	0.060	3.76	$\mu28$	0.075	11.20
$\beta47$	0.670	3.48	$\mu31$	-0.001	-3.54
$\beta55$	0.000	0.17	$\mu32$	-0.00	-0.55
$\beta56$	0.007	5.79	$\mu33$	-0.003	-33.61
$\beta57$	0.001	0.06	$\mu34$	-0.001	-4.51
$\beta66$	0.052	1.21	$\mu35$	-0.000	-25.41
$\beta67$	1.544	7.05	$\mu36$	-0.012	-24.94
$\lambda11$	0.007	13.66	$\mu38$	-0.120	-30.14
$\lambda12$	0.006	32.94	γ	0.116	17.15
$\lambda13$	0.000	3.11	θ	0.117	15.72

Appendix VI : Tables used in Chapter 7.

Table VI.1 : Description of data and variability

Variable	Dimension/base year	Symbol	period : 1971-'92 observations : 4040	
			mean	standard deviation
Price indexes				
Rootcrops	base year 1980	v_1	0.97	0.61
Other outputs	base year 1980	v_2	0.97	0.68
Pesticides	base year 1980	v_3	1.07	1.27
N-fertilizer	base year 1980	v_4	0.91	0.16
Land	1000 guilders	w_1	1.29	0.47
Machinery	-	w_2	0.15	0.02
Quantities				
Rootcrops	1000 guilders of 1980	Q_1	188.85	151.12
Other Outputs	1000 guilders of 1980	Q_2	108.96	94.61
Pesticides	1000 guilders of 1980	Q_3	-19.56	15.24
N-fertilizer	1000 guilders of 1980	Q_4	-7.48	6.11
Other inputs	1000 guilders of 1980	Q_5	-82.14	45.78
Rootcrops area	Hectares	K_1	23.04	15.04
Machinery	1000 guilders of 1980	K_2	135.39	96.27
Total land	Hectares	z_1	47.34	26.57
Labor	man years*10	z_2	15.62	6.73
Trend	1970=0	t	11.75	5.86

Table VI.2 : Estimates of ordered probit model.

parameter	value	t-value	parameter	value	t-value
P_{12}	0.248	1.47	E_{12}	0.006	3.59
P_{22}	0.371	1.13	E_{22}	0.001	2.81
P_{32}	0.238	0.31	G_{21}	-0.008	-7.01
P_{42}	0.242	0.61	G_{22}	-0.018	-4.01
P_{52}	-1.405	-2.03	L_2	0.021	0.77
$M^{-1}{}_{21}$	-0.179	-2.54	c_1	2.210	3.89
$M^{-1}{}_{22}$	3.763	1.21	c_2	1.568	35.09

Table VI.3 : Estimates of system of netput and dynamic factor demand equations.

parameter	value	t-value	parameter	value	t-value
a_{11}	2525.910	5.71	L_1	-0.013	-0.24
a^+_{12}	222.976	0.60	L_2	-0.053	-5.48
a^-_{12}	-5775.800	-0.93	M_{11}	-0.123	-16.36
a_{13}	-92.460	-1.12	M_{12}	-0.001	-1.20
a_{14}	-155.460	-4.05	M^+_{21}	0.2678	4.83
a_{15}	-516.780	-1.01	M^+_{22}	-0.105	-13.64
a_{21}	70.937	0.79	M^-_{21}	0.013	0.09
a_{22}	2115.480	1.29	M^-_{22}	-0.174	-8.12
A_{11}	80.389	0.37	O_{11}	52.454	17.32
A_{12}	153.671	0.90	O_{12}	260.688	20.72
A_{13}	34.229	1.27	O_{21}	53.641	25.51
A_{14}	46.273	2.66	O_{22}	87.871	10.11
A_{22}	-8.034	-0.03	O_{31}	-8.364	-24.31
A_{23}	-46.752	-0.75	O_{32}	-0.451	-0.31
A_{24}	-80.912	-2.25	O_{41}	-4.511	-30.92
A_{33}	171.186	2.54	O_{42}	6.895	11.42
A_{34}	-83.050	-2.26	O_{51}	-18.646	-13.86
A_{44}	22.658	0.56	O_{52}	-32.666	-5.66
B_{11}	0.208	0.01	P_{11}	6.081	10.50
B^+_{12}	-477.870	-1.91	P_{12}	-0.042	-0.40
B^+_{22}	5551.270	0.98	P_{21}	-3.253	-8.07
B^-_{12}	247.318	0.58	P_{22}	0.394	5.33
B^-_{22}	2936.850	0.37	P_{31}	-0.355	-5.48
C_{11}	104.238	1.67	P_{32}	0.035	2.91
C_{21}	50.589	0.90	P_{41}	-0.044	-1.56
C_{31}	-0.493	-0.04	P_{42}	0.028	5.46
C_{41}	3.211	0.52	P_{51}	-1.128	-4.52
C^+_{12}	-1945.68	-3.00	P_{52}	0.250	5.49
C^+_{22}	1954.420	2.64	R_1	188.285	10.89
C^+_{32}	-373.730	-1.33	R_2	44.496	2.98
C^+_{42}	499.449	2.68	R_3	-21.763	-7.13
C^-_{12}	-1214.850	-1.34	R_4	-5.653	-3.37
C^-_{22}	1589.090	1.76	R_5	-32.644	-2.98
C^-_{32}	-381.200	-1.18	S_{11}	-7.738	-9.97
C^-_{42}	488.758	2.37	S_{12}	-6.756	-2.47
D_{11}	-0.128	-2.01	S^+_{21}	-6.999	-0.80
D_{12}	0.246	1.04	S^+_{22}	-94.569	-4.05
D_{22}	-3.373	-2.63	S^-_{21}	17.423	1.22
E_{11}	0.0002	0.01	S^-_{22}	45.815	1.04
E_{12}	-0.003	-1.06	U_1	3.314	0.99
E_{22}	0.001	1.55	U^+_2	12.866	0.35
F	8.858	3.59	U^-_2	33.707	0.80
G_{11}	-0.003	-0.17	σ_{2u}	23.495	2.17
G_{12}	0.001	0.49	σ_{1u}	12.960	0.85
G_{21}	0.013	0.26	H_1	1.234	4.64
G_{22}	-0.015	-1.67	H_2	6.343	6.45

Appendix VII : Netput equations of the Generalised Leontief, Normalised Quadratic and Symmetric Normalised Quadratic

Generalised Leontief

$$q_i = \frac{\alpha_i}{v_i^{0.5}} + \sum_{j=1, i \neq j}^{2} \alpha_{ij} \frac{v_j^{0.5}}{v_i^{0.5}} + \sum_{i=1}^{3} \sum_{j=1}^{3} \beta_{ij} c_i^{0.5} c_j^{0.5} + 2 \sum_{j=1}^{3} \gamma_{ij} \frac{c_j^{0.5}}{v_i^{0.5}} \tag{VII.2}$$

Normalised Quadratic

$$q_i = \alpha_i + \sum_{j=1}^{2} \alpha_{ij} v_j + \sum_{j=1}^{3} \gamma_{ij} c_j \tag{VII.3}$$

Symmetric Normalised Quadratic

$$q_i = \alpha_i + \frac{\sum_{j=1}^{3} \alpha_{ij} v_j}{\sum_{k=1}^{3} \theta_k v_k} - \frac{1}{2} \theta_i \cdot \left[\frac{\sum_{k=1}^{3} \sum_{j=1}^{3} \alpha_{kj} v_k v_j}{\left[\sum_{k=1}^{3} \theta_k v_k \right]^2} \right] + \frac{1}{2} \theta_i \sum_{i=1}^{3} \sum_{j=1}^{3} \beta_{ij} c_i c_j + \sum_{j=1}^{3} \gamma_{ij} c_j \tag{VII.4}$$

Appendix VIII : Elasticities of intensity, shadow prices of fixed inputs and profit after a quota.

Elasticities of intensity after a quota

Profit maximisation under the restriction of a vector of fixed inputs can be depicted analogous to (2.5) as :

$$\pi(v_1,v_2,z) = \max_{q_2}\{v_2 \cdot q_2 + G(v_1,q_2,z);(q_1,q_2,z)\epsilon T; v_1,v_2>0\} \qquad \text{(VIII.1)}$$

Differentiating with respect to v_1 and v_2 results into the netput equations :

$$\pi_{v_1} = q_1(v_1, q_2(v_1, v_2, z), z) \qquad \text{(VIII.2)}$$

$$\pi_{v_2} = q_2(v_1, v_2, z) \qquad \text{(VIII.3)}$$

The same procedure as in section 3.2 can now be followed to obtain the elasticities of intensity, after the introduction of a quota on a former freely disposable netput, from the unconstrained profit function :

$$G_{v_1z} = \pi_{v_1z} - \pi_{v_1v_2} \cdot (\pi_{v_2v_2})^{-1} \cdot \pi_{v_2z} \qquad \text{(VIII.4)}$$

Shadow prices of fixed inputs and profit after a quota

When netput q_2 is constrained at level q_2^*, constrained profit (π^c) is given by :

$$\pi^c(v_1,v_2,q_2^*,z) = G(v_1,q_2^*,z) + v_2 \cdot q_2^* \qquad \text{(VIII.5)}$$

whereas unconstrained profit at level q_2^* is :

$$\pi(v_1,v_2^s,z) = G(v_1,q_2^*,z) + v_2^s \cdot q_2^* \qquad \text{(VIII.6)}$$

Constrained profit (π^c) and unconstrained profit (π) are equal at shadow price v_2^s for the constrained netput that yields q_2^* as the solution in the unconstrained profit function :

$$\pi^c(v_1,v_2^s,q_2^*,z) = \pi(v_1,v_2^s,z) \qquad \text{(VIII.7)}$$

Using (VIII.5)-(VIII.7), the following relation between π^c and π is obtained :

$$\pi^c(v_1,v_2,q_2^*,z) = \pi(v_1,v_2^s,z) + (v_2 - v_2^s) \cdot q_2^* \qquad \text{(VIII.8)}$$

Differentiating (VIII.8) with respect to z yields :

$$\pi_z^c = \pi_z + (\pi_{v_2^s} - q_2^*)\frac{\partial v_2^s}{\partial z} \qquad \text{(VIII.9)}$$

Since the expression between brackets is zero, it follows that the shadow price of fixed inputs after the introduction of the quota can be calculated by inserting the shadow price of the newly constrained netput into the unconstrained profit function (π) (Fulginiti and Perrin (1993)). The effect on profit is calculated by determining the value of π before and π^c after the introduction of the quota.

Appendix IX : Derivation of netput equations under the N-surplus tax

This Appendix shows how the parameters of $G(.)$ in equation (5.4) in Chapter 5 can be obtained from parameter estimates of $\pi(.)$. The results given here are derived from Fulginiti and Perrin (1993) and applied to the situation here, where one input, the quantity of N-fertiliser (q_5), is restricted. The pollution function also contains the area of CO crops, but this area is optimised in a latter stage. Fulginiti and Perrin (1993) derive the following relations between parameters of π and $G(.)$:

$$\begin{aligned} G_{q_5q_5} &= -(\pi_{v_5v_5})^{-1} \\ G_{v_iq_5} &= \pi_{v_iv_5}(\pi_{v_5v_5})^{-1} \\ G_{v_iv_j} &= \pi_{v_iv_j} - \pi_{v_iv_5}(\pi_{v_5v_5})^{-1}\,\pi_{v_5v_j} \\ G_{v_iz_j} &= \pi_{v_iz_j} - \pi_{v_iv_5}(\pi_{v_5v_5})^{-1}\,\pi_{v_5z_j} \end{aligned} \tag{IX.1}$$

where e.g. G_{q5q5} and π_{v5v5} are the second derivative of $G(.)$ to q_5 and π to v_5. Netput equations under a restriction on q_5 are :

$$q_i = \alpha_i - \frac{\alpha_5\alpha_{i5}}{\alpha_{55}} + \sum_{i=1}^{4}\left[\alpha_{ij} - \frac{\alpha_{i5}\alpha_{5j}}{\alpha_{55}}\right]v_j + \sum_{j=1}^{7}\left[\rho_{ij} - \frac{\alpha_{i5}\rho_{5j}}{\alpha_{55}}\right]z_j^{\,\cdot} + \frac{\alpha_{i5}}{\alpha_{55}}q_5 \tag{IX.2}$$

First order condition (5.6) is written as :

$$-\frac{1}{\alpha_{55}}q_5 + \frac{\alpha_5}{\alpha_{55}} + \sum_{j=1}^{4}\frac{\alpha_{5j}}{\alpha_{55}}v_j + \sum_{j=1}^{7}\frac{\rho_{5j}}{\alpha_{55}}z_j + v_5 + \gamma_s v_0 = 0 \tag{IX.3}$$

and can be solved for q_5 as :

$$q_5^* = \alpha_5 + \sum_{j=1}^{5}\alpha_{5j}v_j + \sum_{j=1}^{7}\rho_{5j}z_j + \gamma_s\alpha_{55}v_0 \tag{IX.4}$$

Inserting this in (IX.2) yields netput i equation under the N-surplus tax policy :

$$q_i^* = \alpha_i + \sum_{j=1}^{5}\alpha_{ij}v_j + \sum_{j=1}^{7}\rho_{ij}z_j + \gamma_s\alpha_{i5}v_0 \tag{IX.5}$$

Samenvatting

Vanuit het Gemeenschappelijk landbouwbeleid en het milieubeleid krijgt de landbouw in toenemende mate te maken met restricties die aan haar worden opgelegd. Voorbeelden van milieubeleid die de Nederlandse akkerbouw zullen beïnvloeden zijn het Meerjaren Plan Gewasbescherming en het mineralen beleid. Een doelstelling van het MJP-G is o.a. het reduceren van het gebruik van pesticiden met 39% in 1995 en 60% in 2000. Het mineralen beleid beoogt een reductie van de vervuiling van het grond- en oppervlaktewater door fosfaten en nitraten.

Het gemeenschappelijk landbouwbeleid (GLB) van de EU vormt een andere bron van restricties die aan de akkerbouw in Nederland worden opgelegd. De hervorming die in 1992 plaatsvond houdt in dat prijsondersteuning voor granen drastisch werd verlaagd en dat deficiency payments voor oliezaden werden afgeschaft. Ter compensatie van de ontstane inkomensdaling ontvangen producenten van deze gewassen nu subsidies per hectare. Grote producenten die in aanmerking willen komen voor de hectare subsidies, moeten echter een (tot nog toe per jaar verschillend) percentage van hun areaal met deze gewassen braakleggen. Als gevolg van de hervorming van het GLB zullen de prijzen van met name granen ook meer fluctueren dan het geval was onder het oude regime.

Het bepalen van de effecten van deze beleidsmaatregelen vereist dat de technische details van de maatregelen expliciet worden gemodelleerd. Uitgangspunt bij het bouwen van de modellen in dit proefschrift is de Neoklassieke produktietheorie gebruikt en in het bijzonder de duale benadering daarvan. Bedrijven in de Nederlandse akkerbouw zijn overwegend kleinschalige familiebedrijven, zodat er wordt voldaan aan de voorwaarde die de produktietheorie stelt, namelijk dat producenten prijsnemers zijn in de markten van inputs en outputs.

Zowel de theorie als de toepassing van de statisch (korte termijn) duale modellen is reeds sterk ontwikkeld in de literatuur. Daarom is de eerste doelstelling van dit proefschrift om de korte termijn effecten van de hiervoor besproken beleidsveranderingen te bepalen. De toepassing van de dualiteitstheorie onder prijsonzekerheid verkeert nog in het beginstadium van ontwikkeling. Daarom is een tweede doelstelling van dit proefschrift om een bijdrage aan de literatuur te leveren in de vorm van duaal model onder prijsonzekerheid. Investeringsbeslissingen kunnen worden gemodelleerd met behulp van de dynamische dualiteitstheorie. Toepassingen van de dynamische dualiteitstheorie hebben veelal gebruik gemaakt van geaggregeerde data. Gebruik van panel data levert echter een groot aantal methodologische problemen op. Een derde doelstelling is dan ook om een methode te ontwikkelen om investeringsbeslissingen te modelleren op bedrijfsniveau, met gebruikmaking de dynamische dualiteitstheorie.

Het proefschrift begint echter met een meer algemeen hoofdstuk, waarin verschillende flexibele functionele benaderingen van de winstfunctie worden getest op de dataset van Nederlandse akkerbouwbedrijven die wordt gebruikt voor de te ontwikkelen micro-economische modellen. Getest worden de Genormaliseerde Kwadratische, de Symmetrisch Genormaliseerde Kwadratische, en de Gegeneraliseerde Leontief. Om de verschillende functies tegen elkaar te kunnen testen wordt een Gegeneraliseerde Box-Cox functie ontwikkeld die al deze functievormen omvat als parameter restricties. Een Lagrange Multiplier test, gebaseerd op "Double Length artificial Regression", kan deze parameterrestricties testen zonder dat de Gegeneraliseerde Box-Cox ook daadwerkelijk te schatten. De functievormen worden ook vergeleken op criteria als het voldoen aan regulariteitscondities en de mate waarin parameters significant zijn. Resultaten tonen aan dat de Genormaliseerde Kwadratische functie in zijn geheel genomen beter voldoet dan de overige functievormen.

Een stelsel van heffingen en input restricties is een optie voor de Nederlandse overheid om de doelstellingen van milieubeleid te halen. Wanneer echter een input die voorheen vrij beschikbaar (en dus variabel) was voor producenten, onder een quotumrestrictie komt, heeft dit gevolgen voor de prijselasticiteiten van de overige inputs en outputs. De overheid moet hiermee rekening houden, wanneer zij tegelijkertijd een heffing/subsidie op een andere input of output legt. In hoofdstuk 3 wordt gekeken naar de effecten van een quotering voor pesticiden op prijselasticiteiten, elasticiteiten van intensiteit en schaduwprijzen van vaste inputs. Het effect van de pesticidenquotering op prijselasticiteiten is klein, en het effect op de elasticiteit van intensiteit is afhankelijk van de relatie die pesticiden voorheen had met de variabele inputs (complementen of substituten). Schaduwprijzen van vaste inputs dalen als gevolg van de quotering aangezien pesticiden een complementaire relatie hebben met alle vaste inputs.

De korte termijn effecten van de hervorming van het GLB in 1992 voor de

Nederlandse akkerbouw worden bepaald in hoofdstuk 4. Ten behoeve hiervan, wordt een simulatiemodel ontwikkeld dat bestaat uit vraag- en aanbod vergelijkingen van inputs en outputs die zijn geschat op paneldata van Nederlandse akkerbouw bedrijven. Elk bedrijf in de steekproef heeft een bedrijfsspecifieke technologie door middel van bedrijfsspecifieke (fixed effects) en regionale dummies. De resultaten van de simulaties worden geaggregeerd voor verschillende groepen van bedrijven, en voor de sector als geheel, door het aantal bedrijven in de sector dat elk bedrijf in de steekproef vertegenwoordigt te gebruiken als gewicht. De simulaties tonen aan dat de productie van granen en oliezaden met bijna 9% afneemt in 1996, terwijl de hoeveelheden van de overige outputs nauwelijks verandert. Het nieuwe regime heeft ook een extensivering tot gevolg. De simulaties laten verder zien, dat de meeste grote bedrijven reageren op de beleidsverandering door deel te nemen aan de braakleggingsregeling. Het met het model gevonden percentage van het totale akkerbouwareaal dat wordt braakgelegd komt dicht in de buurt van het werkelijke percentage in 1993.

Het in hoofdstuk 4 ontwikkelde model wordt in hoofdstuk 5 uitgebreid met een module waarin het gebruik van inputs en de samenstelling van het bouwplan worden gerelateerd aan het N-overschot. Het N-overschot wordt op soortgelijke wijze bepaald in de mineralen boekhouding voor akkerbouwbedrijven, die als onderdeel van het mineralenbeleid wordt voorgesteld. In hoofdstuk 5 wordt een methode ontwikkeld waarmee dit soort technische informatie kan worden opgenomen in een econometrisch gebaseerd simulatiemodel, zodat het effect kan worden bepaald van verschillende beleidsmaatregelen. In het hoofdstuk worden de effecten bepaald van een heffing op N-overschot bij verschillende drempels van acceptabele verliezen en van een heffing op kunstmest. Ook wordt gekeken naar de effecten van een verandering van het huidige GLB op het N-overschot. Een heffing van 27 cent per kilo N-overschot bij een drempel van 75 kilo/hectare en een 18% heffing op kunstmest hebben de zelfde vermindering van het N-overschot op sector niveau tot gevolg als een heffing van 1 gulden per kilo N-overschot bij een drempel van 125 kilo per hectare. De N-overschot heffingen geven echter een grotere impuls tot vermindering aan bedrijven met een groot overschot, en hebben op sector niveau een lagere winstdaling tot gevolg dan de heffing op kunstmest.

In hoofdstuk 6 wordt gebruik gemaakt van een "Mean-Standard deviation" nutsfunctie om licht te werpen op het effect van prijsonzekerheid op het gedrag van

Nederlandse akkerbouwers. In het bijzonder wordt getoond hoe de simultane areaal allocatie en input/output beslissingen in een duaal model kunnen worden opgenomen. De specificatie van de nutsfunctie die wordt gebruikt is flexibel genoeg om alle mogelijke risico configuraties van producenten te kunnen testen. Verder wordt een methode besproken om regulariteitscondities van de onderliggende indirecte nutsfunctie te testen. Uit de resultaten van de testen blijkt voor Nederlandse akkerbouwers de risico configuratie "Toenemend Absoluut Risico Avers/Constant Relatief Risico Avers" niet wordt verworpen. Regulariteits condities van de onderliggende nutsfunctie worden verworpen.

In hoofdstuk 7 wordt een methode ontwikkeld waarmee de dynamische dualiteitstheorie kan worden gebruikt om investeringsbeslissingen te modelleren op paneldata. Het ontwikkelde "Threshold model" houdt in dat investeringen nul zijn indien de schaduwprijs van het investeringsgoed zich tussen een beneden - en boven drempel bevindt. Investeringen zijn daarentegen positief (negatief) indien de schaduwprijs van het investeringsgoed hoger (lager) is dan de boven (beneden) drempel. Afzonderlijke vergelijkingen worden geschat voor negatieve en positieve investeringen. De parameters uit beide vergelijkingen zijn significant verschillend van elkaar. Aanpassingstermijnen voor machines voor negatieve investeringen zijn 7-8 jaren voor desinvesteringen en 14 jaren voor investeringen. Ook worden voorwaardelijke (afhankelijk van investeringsregime) korte en lange termijn prijselasticiteiten en elasticiteiten van intensiteit bepaald.

In Hoofdstuk 8 tenslotte, worden een aantal veronderstellingen besproken die in het proefschrift zijn gemaakt en worden resultaten uit verschillende hoofdstukken aan elkaar gerelateerd. Tevens worden enige aanbevelingen gedaan voor toekomstig onderzoek.

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Curriculum

Alfons Oude Lansink werd geboren op 22 augustus 1967 te Fleringen (Overijssel). Van 1979 tot 1985 doorliep hij het Voorbereidend Wetenschappelijk Onderwijs (V.W.O.) op het Twents Carmellyceum in Oldenzaal. Vervolgens studeerde hij van 1985 tot 1987 Nederlandse Landbouw aan de H.A.S in Deventer; deze opleiding werd echter halverwege beëindigd. Na eerst de militaire dienst te hebben vervuld begon hij in 1989 aan de studie Agrarische Economie waarbinnen hij in 1992 in de richtingen Agrarische Economie, Landbouwpolitiek en Agrarische Geschiedenis afstudeerde.
Aansluitend is hij, eerst als Assistent in Opleiding (A.I.O.) en vanaf september 1996 als Post-Doctoraal onderzoeker, verbonden geweest aan de vakgroep Algemene Agrarische Economie van de Landbouwuniversiteit Wageningen.