Agricultural Policy, Land Use and Environmental Effects

Studies in Quantitative Research Synthesis

ISBN 90 5170 712 6

Cover design: Crasborn Graphic Designers bno, Valkenburg a.d. Geul

This book is no. 318 of the Tinbergen Institute Research Series, established through cooperation between Thela Thesis and the Tinbergen Institute. A list of books which already appeared in the series can be found in the back.

VRIJE UNIVERSITEIT

Agricultural Policy, Land Use and Environmental Effects

Studies in Quantitative Research Synthesis

ACADEMISCH PROEFSCHRIFT

ter verkrijging van de graad van doctor aan
de Vrije Universiteit Amsterdam,
op gezag van de rector magnificus
prof.dr. T. Sminia,
in het openbaar te verdedigen
ten overstaan van de promotiecommissie
van de faculteit der Economische Wetenschappen en Bedrijfskunde
op 22 mei 2003 om 10.45 uur
in het auditorium van de universiteit,
De Boelelaan 1105

door

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Acknowledgements

This Ph.D.-thesis is the result of a 4-year-long collaboration between the Department of Spatial Economics at the Vrije Universiteit Amsterdam and the Agricultural Economics Research Institute (LEI) in The Hague. I owe a debt of gratitude to the LEI for the financial support, and in particular to Floor Brouwer who initiated this project. The collaboration was very fruitful and stimulating.

I would never have reached the point of finishing my thesis without the help of others.

First of all, I want to thank my promoter, Peter Nijkamp, for his incredible ability to keep me motivated and to put me back on the 'right boat' at times when I seemed to be lost in the sea of research. My co-promoter and daily supervisor, Raymond Florax, deserves a special word of thanks as well. His optimistic views about research (and life in general) taught me that problems do not need to be obstacles but can be springboards for finding new and better ideas. I also want to thank Henry de Groot and Erik Verhoef for the useful comments they gave on Chapter 6 and Chapter 8, respectively.

The reading committee has strengthened this thesis by providing final and valuable advices. They deserve my gratitude for the time and effort they put into evaluating my work. Furthermore, I want to thank my English proofreader, Dawn Blizard, for her effort and cooperation.

The first 1½ years of work on my Ph.D. were spent at the Tinbergen Institute Amsterdam. Both the courses on a variety of economic topics and the contacts I made there with Ph.D. students from all over the world were very inspiring and mind-broadening. I want to thank all the other Ph.D. students and the Tinbergen staff who contributed to this special experience.

In the second year of work on my Ph.D., I moved to the Vrije Universiteit where I was assigned a desk in the MASTER-point room. Although some members of the Department of Spatial Economics may not fully appreciate this room, I enjoyed staying there, thanks to all my roommates, among which all 'first-generation MASTER-point students', who created a special working atmosphere. All my other colleagues in the Department of Spatial Economics contributed to my work, not only by giving helpful comments and advice at MASTER-point meetings and Eureka lunch-seminars, but also by providing an enjoyable social framework. Arianne deserves a special word of thanks. I am very happy that, over the course of uncountable coffee and lunch breaks, we became friends. Arianne, I really appreciate your indestructible faith that everything will turn out well.

Thanks to a number of other people, the Netherlands became a second home for me. In particular, Anita, Birgit, Cindy, Ellen, Gerben, Karin, Petra, Ruedi, Saskia, Sonja and various members of the gymnastic club C.G.V. DOK Ede brought me many enjoyable hours outside of work. Furthermore, I want to thank Bas' parents, his sister Marij, and the rest of his family for their warm-hearted interest they showed in my work.

My brother, Christian, and his family framed the period in which I worked on my Ph.D. by the birth of my first niece, Maike, in December 1998 and the birth of my second niece, Imke, in September 2002. I want to thank them, as well as all other members of my family and my friends in Germany for the welcome distractions they provided when I left my work behind in the Netherlands for a few days.

Usually Ph.D. students thank their partner for distracting them from their work. But what happens if your partner is also a Ph.D. student? Well, at least you can give each other good advice about putting things in perspective, which you fail to apply to yourselves. Bas, being with you taught me that never quitting always leads to success in the end. Love surely grows stronger the less you try to keep it and the more of it you give away. Bas, thank you for being there.

Last, but certainly not least, I want to thank my parents for making me the way I am, with all the (dis)abilities that make me wonder about myself from time to time. I want to dedicate this book to them. *Liebe Eltern, ich möchte euch dieses Buch widmen. Ihr habt mich zu dem gemacht, was ich bin, mit all den Fähigkeiten, über die ich mich selber auch noch manchmal wundere.*

Katrin

April 2003

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CHAPTER 1

INTRODUCTION

1.1 Backgrounds of the Study

In most western countries, the time when agriculture was considered the nourisher of the nation and the backbone of society has passed. This does not imply that the significance of agriculture has disappeared. In recent years, however, agriculture has attracted public attention mainly by appearing in negative headlines, focusing on overproduction, environmental pollution, BSE, Foot-and-Mouth Disease, pig plague, dioxin contaminated animal feed or genetically modified food. Despite agriculture's increasingly negative image, the sector also provides numerous beneficial services, which are not being discussed in the daily newspapers. For example, agriculture occupies and manages major parts of national land areas, securing the existence of open space and environmental amenities, such as wildlife habitats, groundwater and soils, and space for recreational facilities in an urbanised society.

An anecdotal illustration of agriculture's contrasting connotations concerns the production of maize. In the following two cases, maize that is ultimately used as a fodder crop produces positive as well as negative externalities with respect to its height. In the eyes of the consumer, the height of maize plays an ambiguous role. In the 'Groene Hart',[1] one of the few remaining areas of open space in the densely populated Randstad area of the Netherlands, recreationists complain that from July until September the maize plants exceed a height of 1,80 m, and thus hamper the view of the picturesque landscape with its windmills, cows and ditches (Van der Hoek, 2002).

In other places, the maize needs to exceed a height of 1,80 m to please recreationists, who like to visit fields of maize transformed into so-called cornfield

[1] The 'Groene Hart' is located in the western part of the Netherlands amidst a ring of conurbations consisting of the major Dutch cities of Amsterdam, Utrecht, The Hague and Rotterdam and a number of smaller towns, such as Leiden, Delft and Haarlem. Its area covers about 150 000 hectares, of which 70% is used for agriculture (as opposed to 56% of average agricultural land use in the Netherlands). The national government has approved a restrictive policy for managing new development of housing and industries, office estates and glasshouses for the area of the 'Groene Hart' (http://www.sosnwma.org/regions/reggh.htm, 10-08-2002).

mazes. Cornfield mazes have become popular tourist attractions, especially in the US, Great Britain, Germany and France. They are a good example of the diversifying activities of farmers who have realised that agriculture of the future needs to serve other purposes than the purely productive one.

The cumulative negative effects of agriculture, largely resulting from increasing productivity and production enhancement, have called for rethinking on the part of policy makers, farmers and consumers. The agricultural and agri-environmental policies that are supposed to induce and accompany restructuring of the agricultural sector are the subject of this dissertation. The analysis is explicitly concerned with the agricultural sector and agricultural land use in western industrialised countries, especially in the European Union, but also in other continents, particularly North America. Major issues common to the agricultural sectors of most industrialised countries are the high budgetary costs of agricultural support policies and increasing pressure on environmental resources. This dissertation focuses on the environmental effects of agricultural production and agricultural policy. Special attention will be paid to land as the main production factor in agriculture, since land is recognised as the vehicle through which positive as well as negative environmental externalities become apparent.

In the literature, many studies on the environmental effects of agricultural production and/or agricultural policy can be found (e.g., Brouwer, 2002; Barrett et al., 2001; Shortle and Abler, 1999; Andersen et al., 1999; Plantinga, 1996; Freemark and Boutin, 1995; Arnold, 1983). However, the increasing number of case studies in agricultural and environmental policy research calls for new methods capable of generating new information and insights by combining the results of previously performed primary studies. This dissertation aims at contributing to the literature on agricultural and environmental policy effects by presenting and empirically applying a number of methods for research synthesis based on meta-analytical and comparative analytical principles. The empirical applications provide an indication of the suitability of these methods for generating new knowledge about this field of research.

Apart from this introductory chapter, this dissertation consists of three parts. Part I provides the policy, theoretical and methodological framework by introducing some facts and figures about agricultural land use and about the development of agricultural policy during the past decades. Part I is meant to provide the theoretical background to the policy questions investigated in Part II. Part II consists of three empirical applications, each of them describing a different type of agricultural or environmental policy and addressing varying characteristics and problems. Part III contains a summary and conclusions.

The remaining sections of this introductory chapter give a preview of the issues dealt with in Part I and Part II. Section 1.2 is concerned with the discussion in Part I. It states that the problem of the agricultural treadmill may be regarded as fundamental to the adversities the sector has to deal with currently. Section 1.3 introduces the three empirical applications selected and dealt with in Part II and their characteristic features. Section 1.4 of this introductory chapter contains the objectives and an outline of this dissertation.

1.2 The Agricultural Treadmill

In 1958, Willard Cochrane presented the theory that farmers are on a continually progressing treadmill in their attempts to improve their incomes by adopting new, productivity-enhancing technologies (Cochrane, 1958). How does the agricultural treadmill work? The farming sector is a classical example of a more or less perfectly competitive industry: Many farmers produce uniform products, so that an individual farmer can neither influence the total market supply nor the market price of the produced good. Within the framework of this theory, the two alternatives for an individual farmer to increase his or her profit are either to produce greater quantities at the same production costs or the same quantities at lower costs. Obviously, the two alternatives are reminiscent of the definition of technical progress. Indeed, due to productivity-enhancing technical progress, innovating farmers may be able to earn profits above those of their not-yet-innovating colleagues. However, as innovation disperses, increasingly larger numbers of farmers adopt the productivity-enhancing technologies, which ultimately leads to an increase in total market supply and subsequently to a decrease in the market price. Farmers who are not capable of following the innovation process may not be able to continue farming. The production assets of farmers who cease production, such as agricultural land or production rights, are taken over by other farmers who, through production scale increases, are, in turn, able to enhance production efficiency and to catch short-term profits until declining market prices again erode the income effect evoked by the productivity enhancement (Röling, 2002; Von Witzke, 2001).

The original version of the agricultural treadmill can be regarded mainly as a 'product price' treadmill in which an increase in market supply causes a decline in market prices (Levins and Cochrane, 1996). Simple economic theory suggests that an increase in market supply needs to be accompanied by a proportionally equal increase in demand in order to maintain prices at the same level. Consequently, the agricultural 'product price' treadmill indicates that expanding aggregate supply outweighs the development of aggregate demand. Although the demand for agricultural products in industrialised countries has risen steadily because of population growth and rising per capita incomes, it has not met the large increase in supply that was caused by efficiency enhancements in agricultural production.

Cochrane himself pointed out that in a free market, aggregate supply cannot outweigh aggregate demand indefinitely. If farm price levels decline far enough and stay low long enough, the financial position of farmers will become weak, so that the adoption of new production technologies is no longer feasible (Cochrane, 1958).

However, it is a well-known fact that governmental actions in form of agricultural policy programmes have prevented the downward spiral of agricultural prices in industrialised countries during most of the past century. Stabilised and supported prices have kept farming profitable although productivity improvements have caused market supply to outweigh market demand.

In a short article, titled *The Treadmill Revisited*, Levins and Cochrane (1996) state that farmers are trapped in a new kind of treadmill, namely, the 'land market' treadmill. Their reasoning runs as follows. Due to stable and supported prices, farmers wish to increase production, which can be realised by an increase in scale, i.e., by acquiring additional agricultural land. Consider farmers who are renting their land. Innovating farmers, who are the first to rent additional land in order to adopt new technologies for large scale production, catch short-term profits greater than those of their not-yet-expanding colleagues. However, as soon as other farmers imitate the innovating farmer by renting additional land for production expansion, profits will go back to zero, since the resulting competition for land drives up rents. Farmers who have not yet adopted the new technology are forced to follow the innovators in order to be able to pay the increased rents. Farmers who are not capable of paying increased rents are driven out of agriculture.

How do the two types of agricultural treadmills relate to the content of this dissertation and, in particular, to the issues discussed in Part I? It is generally accepted that technical innovations in the agricultural sector during the last decades, as realised in the intensification of agricultural production, have contributed significantly to environmental degradation in rural areas (Shortle and Abler, 1999). With regard to the second type of agricultural treadmills, the 'land market' treadmill, it is not surprising that production enhancements have taken place through the intensification of agricultural land use. If land becomes the most expensive production factor, it will obviously be substituted by other production factors, such as agro-chemicals capable of enhancing production per unit of land, which may, in turn, cause negative environmental effects.

Describing, illustrating and theoretically underpinning the changes in the agricultural production structure, their resulting effects on the environment and the role of governmental actions are the main concerns of Part I. Part I is intended to supply sufficient information for a thorough understanding of the current malaise in the agricultural sector. This requires the provision of some historical background information on the development of the agricultural sector in general, and on agricultural land use and agricultural policy in particular, as well as information on the economic characteristics of agricultural land use and some information on the theory of policy making. However, Part I is not only concerned with the subjects under investigation, but also with the research methods applied in this dissertation. Chapter 5 of Part I is devoted solely to research synthesis, comparative analysis and meta-analysis. This chapter explains the differences between the three terms, provides an overview of the most important analytical techniques used for comparative and meta-analytical research and offers a brief insight into the most important shortcomings of meta-analytical research.

A further aim of Part I is to introduce the policy problems addressed in the three empirical applications in Part II. These three applications are concisely introduced in the following section.

1.3 Quantitative Research Synthesis: Selected Applications

The three empirical applications selected and investigated in this dissertation concern the effects of agricultural and environmental policy on agricultural land use decision-making and environmental quality. The applications are selected in such a way that they present a broad and multi-faceted picture of different policy types, the ways of implementing them, and their policy targets. The policy questions in the three applications are distinguished according to four main characteristics. The current section offers a concise presentation of the three applications and gives first a brief review of the four main distinguishing characteristics (i) - (iv).

(i) *The type and number of actors involved*

In the literature, the term ‘actors’ is often used as a synonym for ‘stakeholders’. ‘Stakeholders’ can be defined as any group of people, organised or unorganised, who share a common interest in a particular policy question, and who appear at any institutional or administrative level and in any position within society (Grimble and Wellard, 1997). They can be individuals, communities, social groups or institutions of any size, aggregation or level within the society. The group of stakeholders involved in agricultural and environmental issues hence includes a very large number of different types of people in a society, such as public policy makers, public planners, administrators and other government officials on global, national, regional and local levels, farmers and other members of the agricultural sector and the agricultural supply and processing industries and environmental organisations or other types of interest groups. Within the framework of this dissertation, we want to differentiate between actors and stakeholders, or, to be more precise, to consider actors as a subgroup of stakeholders. According to Grimble and Wellard (1997), stakeholders can basically be divided into those who affect or determine policy action and those who are affected by policy action. Alternatively, these two groups may be called active and passive stakeholders, respectively. In this dissertation, we want to define policy actors as stakeholders who are actively involved in a policy-making process, or, in other words, who have a direct influence on the outcome of the policy question under investigation. It is, however, important to note that the distinction between the two groups is not clear-cut. Some stakeholders may be actively involved in the policy-making process, but they may, on the other hand, also be affected by the final policy outcome. This type of stakeholders is characteristic of bottom-up policy approaches, where people in a neighbourhood, i.e., people who are affected by a particular problem, launch an initiative on a local scale (Wallner et al., 1996). An important criterion that characterises the differences between the three empirical applications is whether the main actors in the policy-making process are public or private.

(ii) *The type of administrative level*

The type of administrative level refers to the level of government at which the respective policy described in the three empirical applications is implemented. Different types of environmental problems may require the involvement of different levels of government with different competence, ranging from local and regional to national, supranational and global levels. The policies dealt with in the three applications are initiated and implemented on different administrative and governmental levels.

(iii) *The preciseness of the policy target*

Within the framework of the three empirical applications, the policy target refers, in particular, to the *environmental* policy target. The preciseness of the policy targets therefore implies the extent to which the environment is part of the actual policy target. Policies may be directly aimed at externalities, i.e., at environmental issues emerging from agricultural land use. However, Bateman (1988) points out that land use changes and decisions about land use intensity are generally a by-product of policies designed to meet targets other than environmental ones and that these indirect policies are even more important for land use decision making than direct ones. The policies described in the three empirical applications vary in their definitional preciseness with respect to the environmental policy target.

(iv) *The type of policy compliance*

The type of policy compliance refers to the degree of voluntariness or stringency of policy participation. Most public policies are compulsory, which means that individuals in an economy are subject to their implications. Other types of policies may have a more voluntary character, which means that individuals may decide for themselves whether to participate in a particular policy programme or not. The types of policy in the three empirical applications vary in terms of their levels of stringency, ranging from low to high stringency.

The following paragraphs present the applications' specifics, including the respective appearance of the four aspects just described.

Application A:
Co-operative Agreement between Farmers and Water Supply Companies

Agricultural pollution of the groundwater used for drinking water purposes is increasingly a concern for water supply companies. Water supply companies have to comply with the EU Drinking Water Directive and are hence obliged to deliver drinking water of a certain quality. Their responsibility for drinking water quality forces them to take measures against increasing agricultural pollution, notably residuals of pesticides and fertiliser. An alternative for technological solutions to groundwater purification is to enter into direct negotiations with farmers in order to reduce the emission of harmful substances. Application A focuses on nitrate pollution in groundwater and makes use of survey data on co-operative agreements between water supply companies and farmers in the German state Bavaria. It investigates the relationship between various restraining measures included in the co-operative agreements and the development of nitrate content in groundwater.

Application A is an example of negotiations between two private actors, i.e., farmers and water supply companies. Public authorities may assist in the realisation of co-operative agreements, but the main actors are private institutions. The co-operative agreements described above are a typical example of the bottom-up approach to environmental policy making. They occur at the local level, i.e., the lowest administrative level. The policy target in Application A is nitrate pollution in groundwater, which means that it is clearly directed towards an improvement of the environment. Furthermore, Application A is characterised by low stringency. Farmers may voluntarily take part in a co-operative agreement. Also, water supply companies are not obliged to offer co-operative agreements to farmers. They may choose other ways to protect groundwater if they want to do so.

Application B:
Agri-environmental Policy Programmes in the European Union

Agri-environmental policy programmes in the European Union were introduced along with the MacSharry Reform in 1992. Their main instruments are incentive payments to farmers and they target specific environmental objectives, particular regions, individual sites or particular types of farming or environmental management (Baldock et al., 1993). This application investigates whether the specific conditions under which agri-environmental measures are applied have an effect on the behaviour of farmers. Farmers' behaviour is reflected according to three indictors: the use of nitrogen fertiliser, livestock density and area of grassland with respect to total agricultural area. The data are concerned with several different areas within Europe.

The actors involved in the agri-environmental programmes are governmental agencies and farmers. Depending on the structure of the actual agri-environmental programme, farmers may be directly involved in decision making about the policy measures being applied. Agri-environmental programmes in the European Union are initiated and implemented at different administrative levels. As a part of the reforms in the Common Agricultural Policy (CAP), the EU government has prescribed that Member States are obliged to introduce agri-environmental programmes. However, the actual implementation of the programmes occurs on the national, regional or local level. Agri-environmental programmes of the EU have three major aims. Improving the environment is only one of them. The other two aims are accompanying the changes within the framework of the agricultural policy reform and providing an appropriate income level for farmers (CEC, 1992). Their environmental policy target is hence less precise than in Application A. Furthermore, agri-environmental policy programmes describe a mixture of levels of policy stringency. Whereas the EU Member States are obliged to introduce agri-environmental programmes, farmers are free to choose whether to participate in programmes or not.

Application C:
The Capitalisation of Agricultural Income into Land Prices

Farmers' income is the return on their own labour and the production factors in their possession employed in the production of crops and livestock. Part of the returns are dependent upon different types of financial support for the agricultural sector. On the one hand, support may be channelled through the market price of agricultural products. On the other hand, support payments exist that directly influence farmers' income. Land price theory predicts that agricultural support measures lead to the overvaluation of land, which subsequently increases farmers' capital costs. This implies that high production values, attainable through the use of intensive production methods, are needed in order to earn back these costs. Different types of agricultural financial support may have varying effects on land values. A reduction in land prices may induce a trend towards a less intensive production pattern, which, in turn, may have positive effects on environmental quality in rural areas.

This application is analysed by means of a meta-analysis of studies concerning the impact of agricultural income on land prices. The empirical results of these studies vary considerably, not only due to, for instance, the geographical location considered, the time period covered or the methodological design, but also due to the type of agricultural income indicator used to derive capitalisation of income into land values. The meta-analysis identifies whether different types of support have negative or positive effects on the capitalisation of agricultural income into land prices.

Application C describes a policy that has been, for the most part, created by public authorities, i.e., public actors. On an administrative level, the policy decisions described in Application C are made on national and international levels. They are not only determined by governments on national or EU levels, but also by international negotiations, such as the General Agreements on Tariffs and Trade (GATT). As mentioned above, Application C investigates different types of agricultural support and their effects on agricultural land values. Neither the environmental effect nor the effect on farming intensity of decreasing or increasing land prices is precisely known. Hence there is no clear-cut environmental target. Potential environmental changes may thus be regarded as a by-product or side effect of policy changes. Furthermore, Application C describes a generic policy that applies to all farmers. It is not only farmers who are subject to agricultural policy, but also governments on national and even supranational levels (EU) have to comply with the results of international negotiations on agricultural policies.

The concise descriptions of the three empirical applications have presented the distinct ways the four described characteristics appear in each application. Figure 1.1 summarises the appearance of the four characteristics in Applications A, B and C. It shows that the three applications are logically ordered according to the four characteristics.

According to the availability, structure and characteristics of the data, different impact assessment methods from the field of comparative and meta-analysis were chosen for investigating the three empirical applications. Application A, the co-operative agreements, makes use of rough set analysis, a non-parametric method that is capable of using qualitative as well as quantitative data. Application B, the agri-environmental policy programmes of the EU, employs a meta-analysis based on differences between experimental and control groups. The experimental group consists of farmers that participate in agri-environmental programmes, whereas the control group includes farmers that do not participate in such programmes. Application C, the capitalisation of agricultural income into land prices, applies a meta-regression analysis.

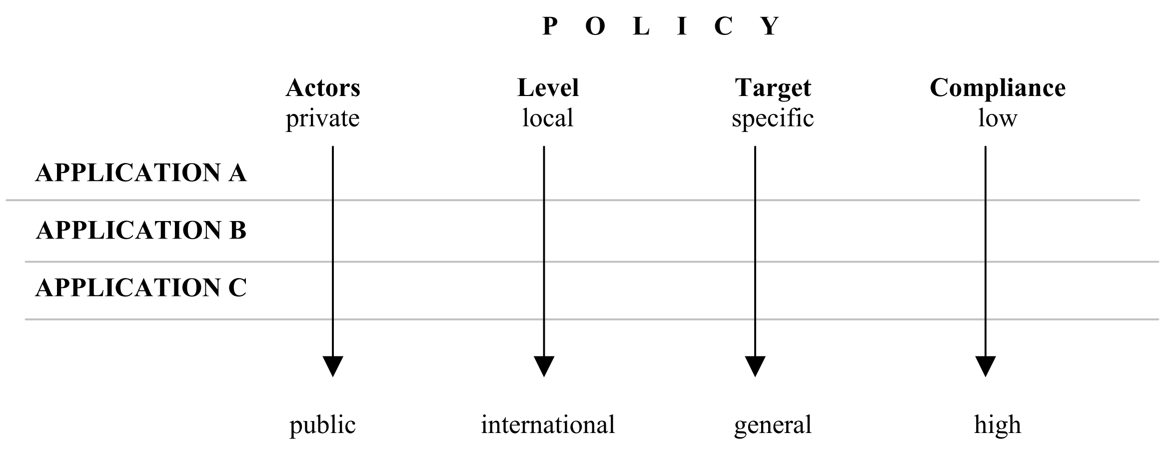

Figure 1.1: Applications ordered according to four characteristics

1.4 Outline and Objectives of the Study

The preceding sections introduced the topic of this dissertation and presented the applications used for the empirical investigations. In particular, the different chapters of this dissertation aim at answering the following research questions.

(i) How have agricultural land use and agricultural policy developed during the past decades?

The first research question serves to give an initial idea of the reasons for the development of the agricultural sector's current situation. In order to gain more insight and a deeper understanding of the development of the agricultural sector in general and agricultural land use and agricultural policy in particular, the following research questions will be addressed.

(ii) What are the main theoretical economic aspects of agricultural land use?
(iii) What is the relationship between agricultural policy, land use and environmental effects from a theoretical and empirical point of view?
(iv) What is the impact of agricultural policies, given specific characteristics, namely
   a) the type of actor (public, private)
   b) the policy level (local, national, international)
   c) the policy target (preciseness of environmental target)
   d) the level of compliance with the policy
(v) What is the potential of research synthesis in agricultural policy and land use analysis?

Figure 1.2 schematically shows the organisation of the chapters that attempt to answer the research questions. The framework of this dissertation consists of a theoretical/descriptive part and an empirical part. The theoretical part, Part I, provides the necessary information and underpinnings for a thorough understanding of the policy problems addressed in the empirical part. It basically addresses research questions (i), (ii) and the theoretical part of (iii). Chapter 2 serves as an introduction to the theoretical part. It introduces some facts and figures about agricultural land use and policy and it presents the issues that are further elaborated upon from a theoretical perspective in Chapters 3, 4 and 5. Chapter 2 serves to address a significant portion of research question (i), which means that it describes the development of the agricultural sector in general and agricultural land use and agricultural policy in particular from a historical perspective. Chapter 3 discusses the reasons for policy intervention in agricultural land use and questions why these conditions occur in the first place. Main concepts that are discussed here are externalities, property rights, optimal allocation among different land uses and land rent and values. The aim of this chapter is twofold. Firstly, it provides some basic theory on the concepts required for understanding the reasons for policy intervention. Secondly, the given theory is applied to the policy questions that are investigated in the three applications in the empirical part of this dissertation. Key points within research question (ii) and the theoretical side of research question (iii) are addressed in this chapter.

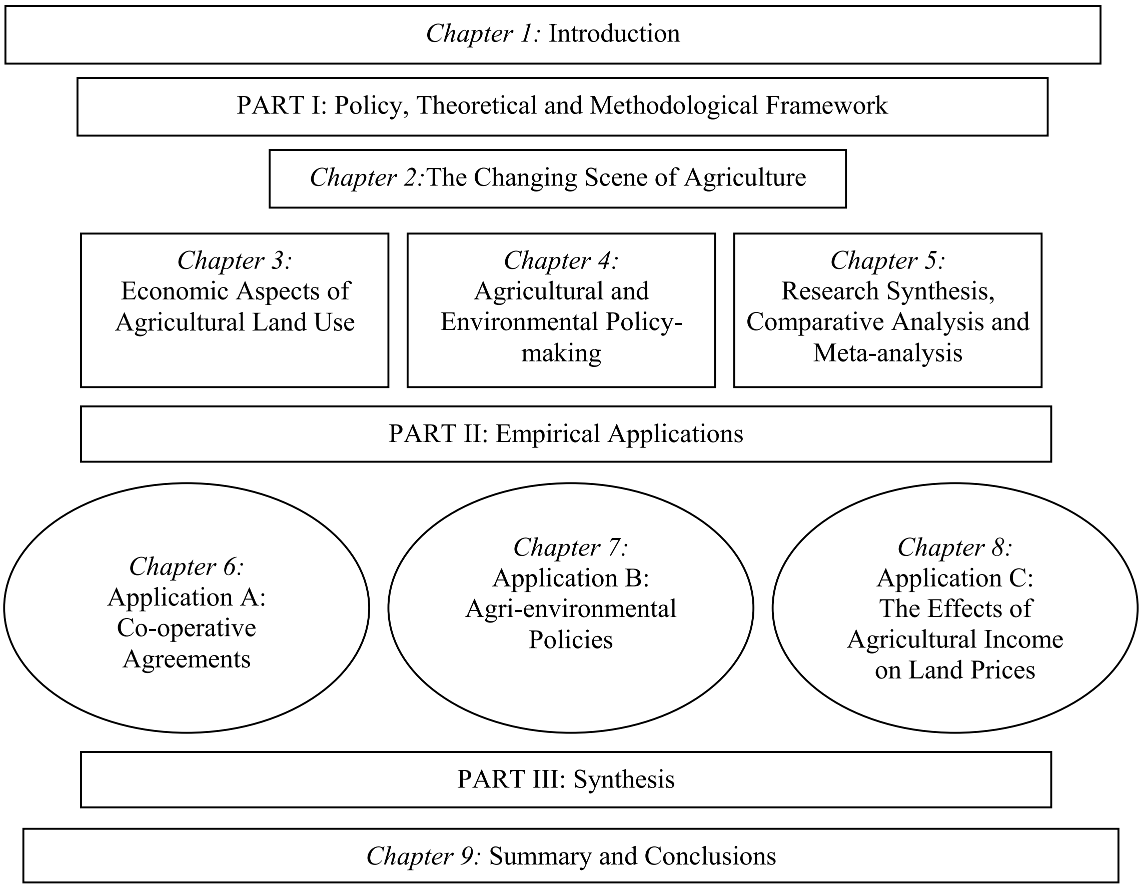

Figure 1.2: Outline of the dissertation

Since the reasons for and background to policy intervention will have been defined by this point, Chapter 4 is concerned with the policy-making process itself. The chapter starts by identifying the overall policy goal employed in many fields of policy, viz. sustainable development, and the measurement of sustainable development by means of indicators. It continues with a description of the policy-making process, placing special attention on selected aspects of it, i.e., the different actors involved in the process, the level of government and policy instruments involved and their compliance with the policy.

Chapter 5 introduces comparative analysis and meta-analysis as methods for research synthesis. In order to gain insight into the actual meaning of research synthesis, comparative analysis and meta-analysis, Chapter 5 provides an in-depth description of the three terms and, in addition, defines the differences and similarities between them. Furthermore, Chapter 5 introduces the analytical methods applied in the three empirical applications.

Chapter 6, 7 and 8 contain Applications A, B and C, respectively; these have been introduced in Section 1.3. The empirical applications serve, on the one hand, as illustrations of different types of quantitative research synthesis. On the other hand, the applications are supposed to give some empirical evidence of the effects of agricultural and environmental policies on agricultural land use and the environment. Chapter 9, which forms Part III, contains a summary, the conclusions and some ideas for further research.

PART I

POLICY, THEORETICAL AND METHODOLOGICAL FRAMEWORK

Chapter 2

THE CHANGING SCENE OF AGRICULTURE

2.1 Introduction

The agricultural sector in most industrialised economies has to struggle against many kinds of adversity. The general problems of and opportunities for the agricultural sector are the subject of this chapter, which has several objectives. Firstly, it aims at placing this dissertation into an overall context and attempts to depict the current conditions in the agricultural sector. This task is completed through the provision of a concise historical description of the development of the agricultural sector in general and agricultural land use and agricultural policy in particular. In addition, this chapter provides important facts and figures concerning the development of agricultural land use and agricultural policy. Such developments and their economic and environmental effects have been considered in numerous studies. The results of such studies are, however, often presented in a scattered and fragmented way. This dissertation provides an approach to integrating the information given in former studies on the basis of comparative analysis and meta-analysis. This chapter also provides an initial overview of the concept of meta-analytical and comparative research.

Section 2.2 describes the developments in the agricultural sector from a historical perspective. Section 2.3 introduces some facts and figures concerning the positive and negative effects of agricultural land use and points out the main reasons why there is a need for public intervention. Section 2.4 gives an overview of the development of agricultural policy since World War II and the current status of agricultural policy in western countries. The ideas behind comparative research and research synthesis are introduced in Section 2.5. Section 2.6 concludes with some prospective remarks.

2.2 Shifts and Dilemmas in the Primary Production Sector

Ever since the society of hunters and gatherers evolved into a society based on a sedentary lifestyle, agricultural systems have been the dominant sources of food supply for human beings. Although more than one factor has stimulated the development of agriculture, it is widely accepted that population growth is a principal driving force for societies to begin cultivating crop plants and domesticating wild animals. After all, agriculture has two major advantages over pre-agricultural systems. It increases the amount of food produced per unit of area, and it has the ability to artificially manipulate yields, which has become especially important since the invention of artificial fertiliser by Liebig in 1840 (Cleveland, 1994; Andreae, 1981; Birnie, 1962).

The evolution and development of agriculture goes along with increasing urbanisation and civilisation, leading to the spatial organisation of large agricultural and rural areas versus concentrated urban areas. Prior to the Industrial Revolution in the second half of the nineteenth century, the two parts of the spatial system co-existed within a relationship of mutual dependence. The agricultural areas supplied food and fibre to the urban areas, the growth of which was, to a considerable extent, sustained by the processing, marketing and trading of those products. However, emerging industrialisation increased the demand for non-agricultural products, implying that urban growth lowers urban dependence on the supply of agriculturally produced goods. The relationship between agricultural and urban-industrial areas has changed into a one-sided dependency of the agricultural area on the urban core, a situation that is often referred to as heartland-hinterland relationship. The heartlands, with their high concentration of the labour force in manufacturing, industry and the service sector and their high capacity to generate innovative changes, determine the types of resources and products the hinterlands (the rural and agricultural areas) need to supply. Development and growth of the hinterlands is thus dependent in all aspects on the activities of the heartlands (Berry et al., 1976).

After World War II, when most of Europe's population experienced periods of hunger and starvation, agriculture again acquired a prominent position in society. The main objectives on the agricultural policy agenda were the enhancement of agricultural productivity, a high degree of self-sufficiency, stable markets, a reasonable level of income for farmers and acceptable prices for consumers. These policy goals were widely accepted, irrespective of the consequences for nature and the environment. Half a century later, their obviousness and the well-accepted position of agriculture in society have disappeared. Increasing awareness of the negative environmental effects of intensive agricultural production and recent difficulties in the agricultural and food industries have seriously raised consumers' concerns about nature conservation, food safety and animal health. As a result, the focus of agricultural policy has shifted from producer protection to consumer protection. Obvious signs of this development are changes in the names of the ministries of agriculture in the UK and Germany. The term 'agriculture' does not appear at all in the new name of the UK's ministry, which is now called the 'Department for Environment, Food and Rural Affairs'. Germany credits agriculture only at the end of the line in the new name 'Ministry of Consumer Protection, Food and Agriculture'.

These trends raise the question of the actual importance of primary agricultural production in Western Europe. Does primary agricultural production still have a right to exist? Most notably in the Netherlands, there are voices that plead for the total abolition of productive agriculture in their country. A main argument for this position is that agriculture is occupying land that may better be allocated to alternative uses, such as water storage, nature conservation, recreation and housing. The Netherlands 'suffers' from an abundance of food and a lack of nature. Food production in an urbanised country such as the Netherlands may sometimes almost be regarded as an illogical thing to do.[2] Although such a statement may seem provocative, in light of the increasing liberalisation of agricultural markets it is indeed questionable whether primary agriculture in the Netherlands will be able to compete with that of countries that can produce much more efficiently on larger scale, such as the Eastern European candidate countries that are supposed to enter the EU. Nevertheless, a recent document created by the Dutch Ministry of Agriculture, Nature and Fisheries reports on the future competitiveness of Dutch agriculture. Massink and Meester (2002) indicate that agriculture in the Netherlands is indeed viable, even when agricultural trade is increasingly liberalised with third countries and when the candidate countries in Eastern Europe enter the EU. In general, there seems to be agreement among advisors and policy makers that the future of European agriculture should not only lie in efficiency improvements but also in diversification, quality improvements and the multifunctionality of agricultural land use. Regional products of high quality produced according to high environmental standards may distinguish themselves from the unitary products on the world market and may respond to consumers' concerns about food safety.

2.3 Challenges in Agricultural Land Use

Agriculture distinguishes itself from most other economic activities by employing land as a principle capital input (Reichelderfer and Randall, 1993). In most countries in the developed world, the contribution of primary agriculture and the food processing industry to the Gross Domestic Product (GDP) is small. For both sectors, the average Gross Value Added as a percentage of GDP lies around two percent. Exceptions are Turkey, Greece and New Zealand, where primary agriculture contributes 14, 5.4 and 5.4 percent of the GDP, respectively (OECD, 2001a). The Netherlands has a strong food processing industry, contributing ten percent of the GDP (LEI, 2002).

Despite the generally limited importance of the agricultural sector to national accounts, agriculture occupies a large part of a nation's land resources. The following figure shows the development of agricultural land as a percentage of total land area between 1960 and 2000 for three selected regions.

[2] This statement has been made by Pieter Verijken, a researcher at Plant Research International (Wageningen University and Research Centre), as reported in Wb 20, 20 June 2002.

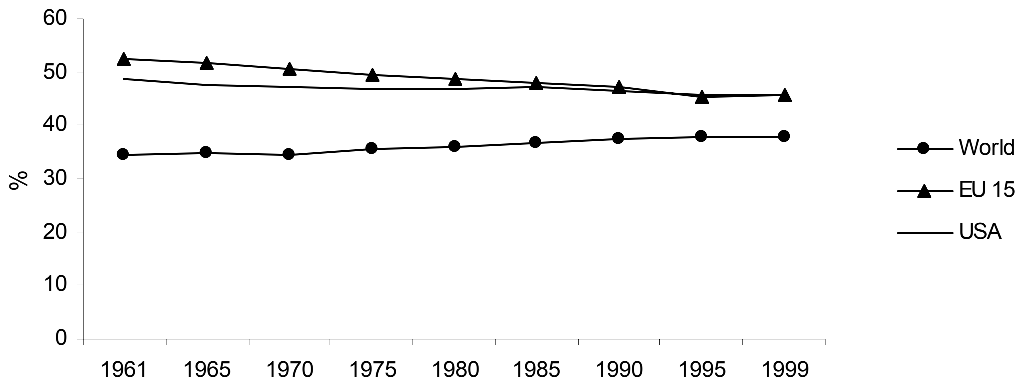

Figure 2.1: Agricultural land as a percentage of total land area for selected regions between 1960 and 2000 (Source: FAO, 2002)

Figure 2.1 shows that, in the 1960s, the percentages of agricultural land in the EU 15[3] and the US have been far above that on a world level, with a converging trend emerging since the 1970s. Reasons for an increasing (decreasing) share of agricultural land on global (EU 15 and US) levels are the following. On a global level, massive land use conversions, mainly from natural ecosystems, such as forests and savannahs, to cultivated land and pastures have taken place during past decades. The main driving force behind land use conversions is the increasing requirement for food due to population growth, especially in the developing world (Fresco, 1994). In the European Union and the US, agricultural productivity increases have resulted in self-sufficiency and even in substantial surpluses. In order to cut down on overproduction, agricultural land is being successively taken out of production and reallocated to nature (Rabbinge et al., 1994). Mainly marginal land in less fertile areas has been taken out of production. The landscapes of fertile regions have remained relatively unchanged, leading to a polarisation into regions of intensive agricultural production and regions of marginal production that may eventually face the abandonment of agricultural land (Baldock et al., 1996; Reenberg and Baudry, 1999). Expanding urbanisation, industrialisation and infrastructure are another important reason for agricultural land's decreasing share in total land use (Gardner, 1977).

There is, however, a justification for why agriculture is the biggest land user in most developed countries. Agricultural land not only serves as a source for economic returns, but also preserves habitats and biodiversity, provides a carbon sink, and contributes to the conservation of water and soil resources (OECD, 1998a). Both cultivated plant species and many weeds in cultivation might become extinct without

[3] The EU 15 includes Finland, Sweden, Denmark, Germany, the Netherlands, Great Britain, Ireland, Belgium, Luxembourg, France, Austria, Spain, Portugal, Italy and Greece. In the text, EU 15 refers to these countries alone. "European Union" refers to the EU in general, regardless of differences in membership over time.

the cycle of cultivation, harvesting and seed storage. Furthermore, crops and, in particular, their residues after harvesting form a valuable source of food for migratory birds (Steenblik et al., 1997). Along with these important functions for flora and fauna, agricultural land also contributes to the preservation of open space and the maintenance of characteristic landscape elements; these aspects are largely responsible for the recreational value of agricultural land. The agricultural and environmental economics literature includes many studies on the (recreational) value of agricultural land, applying monetary valuation methods, such as contingent valuation or travel cost approaches (e.g., Brouwer and Slangen, 1998; Brunstad et al., 1999; Drake, 1992; Fleischer and Tsur, 2000; Furuseth, 1987; Hanley et al., 1998; Kline and Wichelns, 1996; Pruckner, 1995; Willis and Garrod, 1993).

Despite its beneficial functions, intensive agricultural land use also generates harmful environmental effects. The most prominent examples of these effects are ground and surface water pollution due to the run-off of artificial fertiliser, livestock manure and pesticides, soil erosion, the degradation of habitats, biodiversity and landscape due to upscaling and production specialisation, and the emission of nitrous oxide, a greenhouse gas contributing to climate change (OECD, 1998a). Table 2.1 gives an overview of important environmental impacts from different agricultural practices. The environmental impacts are categorised into four different environmental media: air, water, soil, and nature, wildlife and landscape.

Describing the full range of environmental impacts mentioned in Table 2.1 in detail would go beyond the scope of this chapter. In the remainder of this section, we want to concentrate on aspects around fertilisation. Euthrophication and acidification resulting from over-fertilisation and manure surpluses are the most relevant impacts from agricultural practices on the environment in the Netherlands. The amount of money spent on measures against eutrophication and acidification from Dutch agriculture rose from 43 million Euro in 1990 to around 95 million Euro in 2000 (RIVM, 2001).[4]

To get an idea of the environmental pressure caused by over-fertilisation and manure surpluses, consider Figure 2.2. As an example of an environmental indicator, this figure shows the estimated soil surface nitrogen balances for selected regions, among which the Netherlands, between 1984 and 1997.

[4] These costs include capital and operating costs on an annual basis for measures that have a positive effect on the environment. They include expenses made by private persons and public authorities.

Table 2.1: Overview of important environmental effects from different agricultural practices
(Source: EEA, 1995)

Agricultural practice	*Environmental media*	Air	Water	Soil	Nature, wildlife and landscape
Specialisation and concentration	Increasing field size, removal of vegetation cover and land consolidation		• removal of vegetation cover → increased surface runoff → sedimentation, eutrophication	• removal of vegetation cover → soil erosion • inadequate management → soil degradation	• loss of hedgerows, woodlands and small watercourses → decrease in landscape variety and species reduction
	Intensive animal husbandry	• emissions of methane and ammonia	• silage effluent → organic matter and nutrients in water bodies	• spreading of manure high in heavy metal content → elevation of soil concentration	• construction of storage silos → changed landscape
	Intensive cropping		• soil erosion → increased sediment runoff → water pollution	• loss of organic matter in soil → decline in soil fertility and absorption capacity → increased erosion and runoff	• changed landscape through increasing field size and land consolidation
Fertilisation	Animal manure	• ammonia and nitrous oxide volatilisation • unpleasant odours	• spills of organic matter and nutrients to water bodies → eutrophication → oxygen depletion → excess algae and water plants, fewer fish • leaching to groundwater → pollution of drinking water supply	• accumulation of heavy metals and phosphates in soil → may enter the food chain • overapplication → soil acidification	• potential loss of nutrient poor habitats
	Mineral fertiliser	• ammonia and nitrous oxide release	• nitrate leaching and phosphate runoff → elevated nutrient levels → eutrophication of fresh and coastal coastal waters, contamination of aquifers	• overapplication → local acidification → deterioration of soil structure, imbalance in nutrients	

Pesticides application		• evaporation and pesticide drift → adverse effects in nearby ecosystems	• leaching of residues and degradation products → impacts on fish and other water animals and on drinking water resources	• accumulation of persistent pesticides • use of broad spectrum pesticides → impacts on soil microflora, may affect or eradicate non-target organisms	• possible wildlife poisoning incidents in non-target organisms • loss of habitat and food source for non-target species • resistance on some target organisms
Irrigation and water abstraction			• lowering of the groundwater table → soil salinisation and alkalinisation → impacts of surface and groundwater quality → drinking water • high abstraction required for some crops → strain on resources in some areas	• waterlogging → salinisation and alkalinisation of soils • use of saline of brackish waters for irrigation in hot climates → increased salt precipitation and carbonates	• soil salinisation and alkalinisation → desertification and losses of species • drying out of natural elements affecting river ecosystems
Drainage		• chemical changes in soil → greenhouse gas emission	• lowering of the groundwater table	• oxidation of organic soils → acidification and changes in soil structure	• loss of wetlands and changes in botanical composition of grassland, fens and other habitats
Mechanisation	Tillage, ploughing	• increase in dust and particulate matter in air	• increased surface water runoff → sedimentation, eutrophication	• ploughing up and down slopes → soil erosion	
	Use of heavy machinery	• increased CO_2-emission	• chemical changes in soil → greenhouse gas emission	• compaction and erosion of top soil	

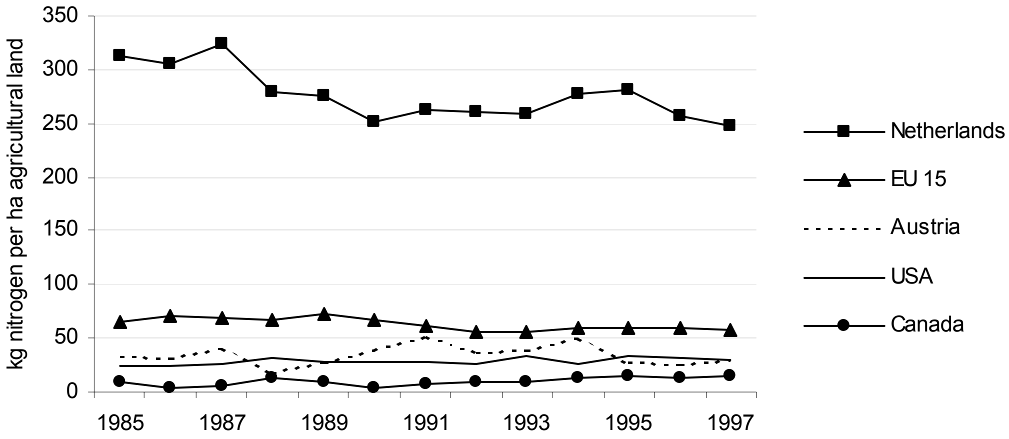

Figure 2.2: Soil surface nitrogen balances for selected regions between 1985 and 1997 (Source: OECD, 2002)

Nitrogen balance is the difference between nitrogen inputs (inorganic fertiliser, livestock manure, biological nitrogen fixation, atmospheric deposition, organic fertiliser and seed and planting materials) and nitrogen outputs (absorption capacity of plants measured by harvested crop production and grass and fodder crop production) (OECD, 2001a). It is obvious from Figure 2.2 that in all selected regions nitrogen input exceeds nitrogen output, although the magnitude of the nitrogen surpluses differs considerably between regions. On average, agricultural production in the EU 15 seems to be more nitrogen intensive than in the US and Canada, although within the EU 15, there are significant variations in the nitrogen surpluses among countries. The Netherlands produces by far the largest nitrogen surpluses, whereas in Austria the nitrogen surpluses are the lowest and are comparable to those in the US. It appears that, especially in the Netherlands, nitrogen surpluses are showing a decreasing trend. The expenses that have been made in order to reduce eutrophication and acidification seem to have an effect. In several other countries in the EU, nitrogen surpluses are decreasing, which can be seen in the slight decline in average surpluses within the EU 15. In the other selected regions, nitrogen surpluses are fairly constant.

Agricultural land use decision-making can either be made along the intensive or the extensive margin. Changes at the intensive margin occur through increasing production per unit of land, either by means of increasing input use or by changing to higher-valued crops. Changes at the extensive margin occur through taking formerly unused land into production (Van Kooten, 1993). The decreasing shares of agricultural land in the US and the EU 15, which were shown in Figure 2.1, in combination with the increasing production values realised in these regions during the past decades, lead to the conclusion that production increases have been realised at the intensive margin, i.e., through increasing production per unit of land. Alston et al.

(1995) find an average annual growth rate of land productivity (measured as output per unit of land) of 1.6 across OECD countries between 1961 and 1990. The growth rates range from a negative rate of -0.10 in Japan to a very high positive rate of 3.14 in the Netherlands. In comparison, labour productivity (measures as output per unit of labour) exhibits an even higher growth rate over the same period. The average annual growth rate across OECD countries is 4.0, ranging from 1.35 in New Zealand to 6.01 in Belgium-Luxembourg.

Technical change in agriculture is biased towards land and labour-saving technologies. The theory of induced innovation says that technical change should be directed towards reducing the use of relatively high-priced production factors (Hayami and Ruttan, 1985). If technological progress has been land-saving, it can be concluded, on the basis of the theory, that the price of land relative to the prices of other agricultural inputs, particularly agricultural chemicals, has been rising, assuming that the theory is valid. In fact, Hayami and Ruttan (1985) note that more than 90% of variation in fertiliser use between 1880 and 1980 can be explained by variations in the fertiliser-land ratio. Figure 2.3 illustrates the development of the land rent-fertiliser price ratio for the Netherlands between 1980 and 1995. Land rent represents factor costs for land. Fertiliser price is the price of nitrogen fertiliser paid by the farmer.[5] Keep in mind that the Netherlands has the highest annual average growth rate of land productivity for all OECD countries.

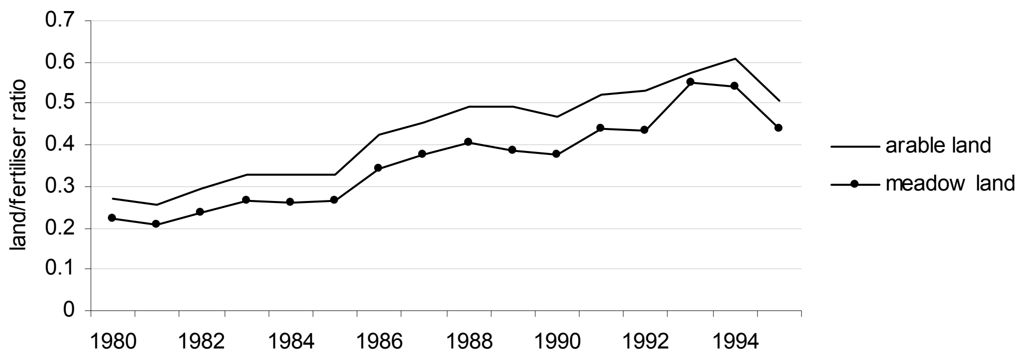

Figure 2.3: Development of land rent/fertiliser price ratio for the Netherlands (Source: CBS, 2002; FAO, various years; own calculations)

Figure 2.3 shows that the land rent-fertiliser price ratio more than doubled between 1980 and 1995 both for arable land and for meadow land, which indicates technical change biased towards land saving technologies. To put it differently, agricultural land use decision making has occurred along the intensive margin,

[5] The price of nitrogen fertiliser is represented by the price of calcium ammonium nitrate measured per metric tonne of nutrient. Calcium ammonium nitrate has by far the greatest share in total nitrogen fertiliser consumption.

implying an intensification of agricultural production, which increases the danger that negative production externalities will occur.

It would obviously be desirable to increase the positive environmental effects of agricultural land use and to reduce the negative ones. The following section describes the agricultural policy regime that is assumed to be one of the causes of current environmental problems. It also presents an overview of policies that are meant to mitigate the environmental pressure from agriculture and that aim to initiate a restructuring of the agricultural sector.

2.4 Agricultural and Environmental Policies

In most industrialised countries, traditional agricultural policy is marked by substantial financial support to agricultural producers. After World War II, the most important policy issue in agriculture was the security of food supply, an objective that should be reached by enhancing agricultural productivity (Mahe and Ortalo-Magne, 1999). Assisted by a range of protective policy instruments, such as price stabilisation, export subsidies and import duties, the agricultural sector experienced considerable productivity improvements. These improvements were mainly caused by the intensification, specialisation and concentration of production (Potter and Goodwin, 1998; Bowler, 1986).

To give an impression of the extent and development of financial support of agriculture, Figure 2.4 shows two panels with agricultural support indicators for the European Union, the US and the OECD between 1986 and 2000.

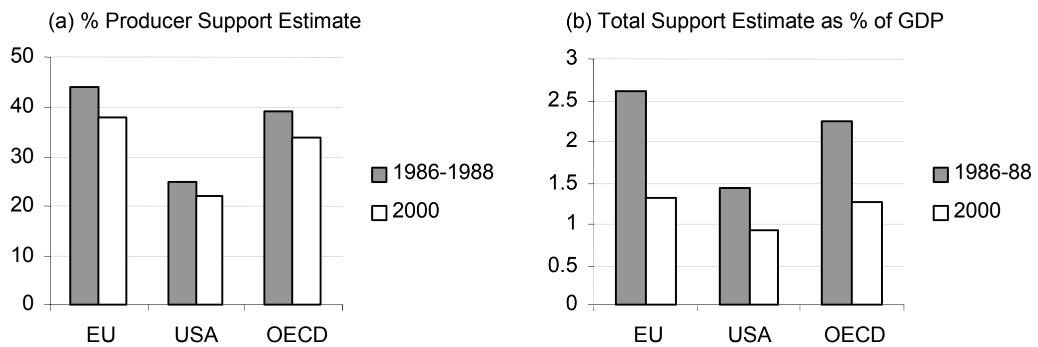

Figure 2.4: Agricultural support indicators
(Source: OECD, 2001a)

Panel (a) depicts the Producer Support Estimate (PSE), an indicator of the annual monetary transfers from taxpayers (through government budgets) and consumers (through domestic market prices that are supported at levels above world market prices) to agricultural production. Here, the PSE is presented as a percentage of gross farm receipts (% PSE), which indicates the share of production value at the farm gate stemming from public transfers. Panel (b) shows the Total Support Estimate (TSE), an indicator of the annual monetary transfers from taxpayers and consumers arising from policies supporting agriculture. TSE, expressed as a percentage of GDP, is an indication of the burden overall agricultural support places on the economy (OECD, 2001a; Legg, 1996).

Panel (a) implies that agricultural support is substantial, although, as shown in Panel (b), its burden on the economy declined in all three regions during the 1990s. The European Union leads in both panels. In 1986-88, the contribution of public transfers to gross farm receipts approached 50%, declining to less than 40% in 2000. Whereas the relative decrease of %PSE was moderate in all three regions, the relative decrease of TSE as a percentage of GDP was reasonably high. This indicator nearly halved in the European Union and the OECD between 1986 and 2000, which may imply that GDP has grown at a faster rate than the financial burden due to agricultural support has decreased.

Puccinini and Loseby (2001) point out that with respect to productivity improvements, financial support of agriculture has not been wasted. Agriculture is one of the sectors of the economy with the highest increases in productivity per unit of capital and labour. Figure 2.5, which shows the Net Agricultural Production Index (PIN)[6], gives an indication of productivity increase on EU 15, USA and world levels between 1960 and 2001.

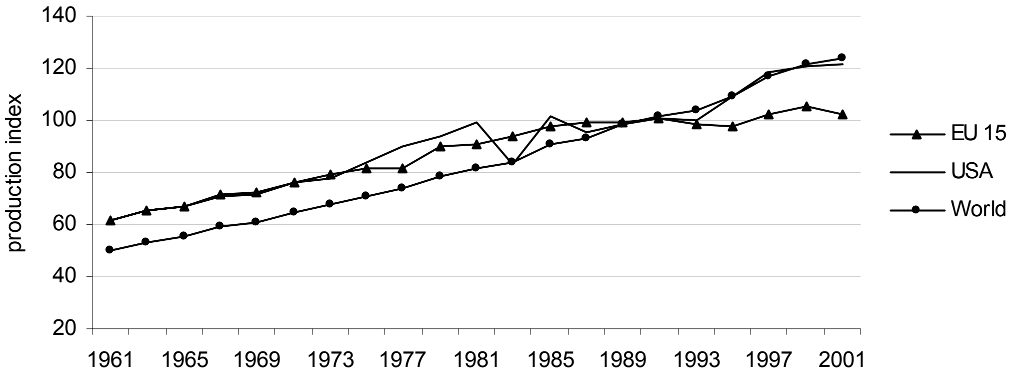

Figure 2.5: Net Agricultural Production Index, base 1989-1991
(Source: FAO, 2002)

[6] PIN presents net production (production minus feed and seed) indices that are calculated by the Laspeyres formula. Net production quantities of each commodity are weighted by 1989-91 average international commodity prices and summed for each year. To obtain the index, the aggregate for a certain year is divided by the average for the base period 1989-91. Indices are calculated from net production data presented on a calendar year basis (http://www.fao.org/waicent/faostat/agricult/pinelint-e.htm, 20-06-2002).

Figure 2.5 depicts a rapid increase of the PIN for all regions during the last 40 years. On the world level, agricultural production shows the greatest increase, from about 50 index points in 1961 to more than 120 index points in 2001. It is interesting to note that, especially in the US and the EU 15, production growth was induced by domestic market demands during the 1960s. In the 1970s it was mainly the foreign trade sector that offered opportunities for market expansion and hence grounds for further production increase (Alexandratos, 1990). In particular, on the EU 15 level, it becomes obvious that production increases have slowed during the 1980s, remained fairly constant since the beginning of the 1990s and have even been decreasing over the last couple of years. The slow-down in production increases during the 1980s may be due to the introduction of a number of production-restricting measures, such as guarantee thresholds for grain and oilseeds in 1982 and 1988, respectively, and the dairy quota in 1984 (Ingersent et al., 1998). The stagnating production index during the 1990s in Europe may be the result of the Common Agricultural Policy (CAP) reform. Two major components of the CAP reform are price cuts for main arable crops (cereals, oilseeds and protein crops) and the introduction of compensation payments in the form of fixed area payments. In order to be eligible to receive compensation payments, farmers have to set aside part of their arable land, initially 15% of it (Puccinini and Loseby, 2001; Ingersent et al., 1998).

There are several reasons why a reform of the CAP was inevitable. The productivity improvements made the protective policy strategy of the CAP successful in terms of attaining self-sufficiency for most agricultural commodities. In fact, the policy strategy overshot the mark in the sense that it brought about substantial overproduction and commodity surpluses. An important argument for reaching self-sufficiency was that the domestic market should not be dependent on foreign food imports, which would be positive for the national balance of payments. However, a counterargument is that intensive agricultural production is dependent on other kinds of imports, in particular, fuel, fertiliser and raw material for high-energy feed (Body, 1982). Overall, the protective policy strategy placed an increasing burden on the budget, caused by mounting commodity surpluses that had to be dumped on the world market with the help of subsidised exports. On a global scale, the World Bank notes that the protective agricultural policies of the industrial countries are responsible for impeding agricultural and economic development and delaying the mitigation of malnutrition and poverty in the developing world (World Bank, 1986).

Agricultural policy reforms are being implemented in all OECD countries. The first commitment of OECD Agricultural Ministers to reform agricultural policy was made in 1987. Reinforced by the 1994 Uruguay Round, the OECD Agricultural Ministers affirmed this commitment in 1998. The main elements of these reforms are a reduction in support levels, the liberalisation of agricultural trade, increasing access for imports and a reduction in export subsidies and trade-distorting domestic policy measures (Legg, 2000). With respect to the environment, there are indeed indications that lowering price support and input subsidies has lessened some of the damage caused by agricultural production. In some cases, a decrease in demand for chemical inputs and irrigation water as well as a de-intensification of crop production can be observed. However, since reduction in support levels has often been replaced by direct payments based on acreage or per head of animal, there are other cases that do not show any positive environmental effects but rather the opposite, namely shifting production into other input-intensive crops and increasing stocking densities (OECD, 1998b).

Another point of concern is that agricultural support has allowed farmers in marginal regions to maintain particular systems of low-intensity farming, such as semi-natural grassland, that conserve a wide variety of flora and fauna, prevent landslide, have a flood-control function and shape characteristic landscapes valued by the population. These types of farming systems therefore provide positive environmental externalities. Without support, extensive production systems would become unprofitable and their land might be abandoned. In some cases, the abandoned land may be re-integrated into the natural system of vegetation and wildlife, which might be advantageous for the environment. In other cases, the abandoned land could be subject to environmental damage, such as soil erosion and the degradation of biodiversity, landscapes and wildlife habitat (Legg, 2000; Baldock et al., 1993).

In order to maintain low-intensity farming systems, but also to address specific environmental issues through targeted environmental measures, many OECD countries have introduced special agri-environmental policy measures in their reforms. For instance, the US has the Conservation Reserve Program that is mainly focussed on the reduction of soil erosion on fragile land, which is the major concern in terms of environmental damage in this country (Shoemaker, 1989). In the European Union, an Agri-environmental Programme has been introduced along with the MacSharry reform in 1992. Together with the Early Retirement Scheme for farmers and the Afforestation Programme for agricultural land, it is one of the three accompanying measures for stimulating the restructuring of the agricultural sector. In order to respond to differences in geographical conditions, agricultural production systems and rural traditions within the EU, the Agri-environmental Programme is a very diverse and broad instrument. The EU government dictates that there has to be an Agri-environmental Programme in each Member State, but the actual elaboration and implementation of the policy measure takes place on the national, regional or even local level. For example, whereas manure surpluses and water pollution are often the major problems in the densely populated regions of northern Europe, soil erosion, land abandonment and water shortage are important points of concern in Mediterranean countries.

2.5 Methods for Research Synthesis

The preceding sections have described the development of the agricultural sector, agricultural land use and agricultural policy. In addition, they provide an overview of the environmental impacts of agricultural land use, which is heavily influenced by agricultural and environmental policy making. It has been mentioned in the introduction to this dissertation that agricultural and environmental economics literature contains many studies on the environmental effects of agricultural production, land use and policy. It has, furthermore, been pointed out that the increasing number of this type of studies demands new methods for generating new information and insights from previously performed studies. One of the major aims of this dissertation is to present and empirically apply a number of these methods, stemming from the field of research synthesis, such as comparative and meta-analytical techniques. The current section gives an introduction to research synthesis in general and to comparative analysis and meta-analysis in particular as a new methodological framework.

Empirical research in economic science is the main tool for testing theory and exploring particular phenomena that occur under certain conditions, at certain places and at certain points in time. Methods for carrying out empirical research range from case study research, experiments and surveys to the analysis of archival information (Yin, 1994). This dissertation is concerned with case study research and archival information and, in particular, with former studies that apply these types of empirical research.

In the literature, numerous case studies on the same research question can be found. Reasons to repeat studies on the same phenomenon are researchers' unawareness of what others are doing, scepticism about the result of past studies and the desire to extend, generalise or contradict previous study results (Cooper and Hedges, 1994b). The latter reason is especially important when it comes to contributing to scientific knowledge-building. As we know from experience, empirical findings on similar research questions show varying results, are often inconsistent or are even contradictory. Variations in study results may arise from a number of factors, such as different analytical frameworks and differences in the underlying data (e.g., spatial and/or temporal aspects) (Bal and Nijkamp, 2001).

Scientific knowledge-building cannot be attained only by performing new primary empirical studies. Another way of contributing to the stock of knowledge is to synthesise and reassess the findings of previous studies. New insights can be gained from systematically investigating the reasons for variations in former study results, which may, subsequently, lead to theory-building, benefit transfer and new directions for primary research. An appropriate approach to systematic research synthesis is meta-analysis. Meta-analysis offers a range of quantitative techniques that allows the researcher to systematically combine and compare former research results in a statistical fashion. An often-used synonym for meta-analysis is *quantitative literature review* (Stanley, 2001).

Although quantitative comparison of previous research findings has been performed since the beginning of the twentieth century, the term "meta-analysis" was first used in 1976 by Gene V. Glass (Cooper and Hedges, 1994b). An early example of a meta-analytical application can be found in the agricultural literature. In 1931, Jay Lush investigated the relationship between the initial weight of steers and their subsequent weight gains. His meta-analysis consists of averaging correlation coefficients retrieved from six different samples of steers (Rosenthal, 1991). However, the traditional fields of meta-analytical research are medical science and psychology. The evolution of meta-analysis in these fields is, to a great extent, due to the large numbers of case studies on the same question performed in experimental and standardised surroundings, which forms a perfect basis for statistically-based research synthesis (Glass et al., 1981; Hedges and Olkin, 1985; Petitti, 1994). Later, meta-analysis was extensively used in the social sciences and more recently also in economics (Rosenthal, 1991; Van den Bergh et al., 1997; Stanley, 2001; Florax et al., 2002a; Florax et al., 2002).

Strictly defined, meta-analysis applies only to empirical studies that use a quantitative measurement of variables that allows the application of rigorous statistical techniques (Lipsey and Wilson, 2001). However, Van den Bergh et al. (1997) mention that meta-analysis may also include techniques that can handle qualitative and categorical data or data with a certain component of uncertainty. The underlying primary studies may thus also be of descriptive case study format. In fact, the structure of the information given in the underlying primary studies and the objective of the meta- or comparative research will determine the type of technique used for the synthesis (Bal and Nijkamp, 2001).

Meta-analysis is particularly concerned with aggregated data, i.e., summary statistics that describe a population or certain effects in a population. There are, however, also case studies that provide 'original', unaggregated data. The synthesis of this type of case study may be described as comparative analysis. Large research projects, including those that are (co-)financed by the European Commission in the fields of agricultural and environmental research, are often characterised by a number of different participating research teams that carry out case studies on the same question in different regions or countries. The aims of these projects are to get as complete a picture as possible of the answers to a particular question across different regions within countries and to promote the collaboration of research teams within Europe. However, a frequently encountered disadvantage of large research projects is that the results of the case studies are often described in narrative format and the incorporated information is not fully employed in terms of synthesising common and contrasting elements. This is also the case in the two research projects used as a basis for Applications A and B. In order to extract more information from the reported research results, we apply methods of research synthesis to the data provided in the project reports. The actual differences between the terms ‘research synthesis’, ‘comparative analysis’ and ‘meta-analysis’ are further elaborated upon in Chapter 5.

2.6 Conclusions

This chapter has presented background information about the subject of this dissertation and has placed it in a general context. Agricultural land use generates positive as well as negative externalities. Agricultural policy, as it has been performed in industrialised countries in the second half of the twentieth century, has fostered intensive agricultural production methods that in many cases produce the predominance of negative externalities over positive ones. Increasing environmental pressure, as well as the growing financial burdens on the public budget that result from applying the supporting type of policy instruments, has indicated that conventional agricultural policy does not lead to sustainable development. Current reforms of agricultural policies attempt to integrate environmental objectives and aim at stimulating the production of positive environmental externalities. Agricultural and environmental literature contains numerous studies that investigate the effects of agricultural policies and, in particular, reforms of agricultural policies on land use practices and their effects on the environment. Comparative and meta-analytical methods may be appropriate tools for summarising, reviewing and evaluating these studies. Furthermore, new insights may be gained, which will add to the existing knowledge in this research field.

The sections of this chapter introduce the problems and characteristics of the agricultural sector that will further be elaborated on from a theoretical perspective in the following chapters. Chapter 3 focuses on the issues surrounding agricultural land use. It describes the economic characteristics of agricultural land use and explains the reasons for policy intervention. Chapter 4 takes up the topic of agricultural and environmental policy-making. Whereas facts and figures dealing with this topic are presented in Section 2.4, Chapter 4 elaborates some theory on the policy-making process itself. The last chapter in Part I, Chapter 5, further describes comparative and meta-analytical research methods.

CHAPTER 3

ECONOMIC ASPECTS OF AGRICULTURAL LAND USE

3.1 Introduction

Classical economists treat land resources as a limiting factor for the long-term economic welfare of a nation. They explicitly include land, along with capital and labour, in their production functions. In contrast to capital and labour, land is characterised by its fixity in supply, which ultimately results in diminishing returns to other inputs (Randall and Castle, 1985). The law of diminishing returns says that if one production factor is increased while another factor, in this case land, is held fixed, output will initially rise, but the rate of increase associated with the variable production factor will eventually begin to fall, namely at the point of diminishing marginal returns. Diminishing total returns occur at the point where average output begins to fall, with a further increase in the variable production factor (Hirshleifer, 1980).

The classical economist Thomas Robert Malthus (1766-1834) has become famous for his doctrine of population growth and increasing resource scarcity. The Malthusian Doctrine paints a very pessimistic picture of the future of the world's population. It assumes that population increases at a geometric ratio whereas subsistence increases at an arithmetic ratio. This difference in growth structure would lead to a divergence of the two over a relatively short time frame (Barlowe, 1972; Ely and Wehrwein, 1940).

However, mainly due to technological progress in agriculture, increasing knowledge about birth control and the tendency for population growth to slow down as societies get richer, Malthus' hypothesis could not be approved (Koester, 1992). The continuation of technological development, stimulated by the Industrial Revolution, substantial emigration from Europe to America and increasing and reliable imports of food and raw material to Europe from the rest of the world, have led economists to neglect the relevance of land's fixity of supply and diminishing returns. As a consequence, neoclassical economic theory defines land just like any other capital good and leaves land out of its analytical models (Randall, 1987). A further aggregation of capital in production functions was introduced by the Chicago School. They drop the fundamental distinction between capital and labour and use a very broad interpretation of capital that represents physical, human and natural capital (Randall and Castle, 1985).

Nevertheless, Miranowski and Cochran (1993) stress that along with fixity in supply, land as an input for production has other unique characteristics. It is bound to a fixed location and geoclimatic environment that influences its soil characteristics and productivity. It is hence a heterogeneous resource that varies in soil type, topography, climate and cultivated vegetation. The amount of land suitable for specific production processes is therefore relatively limited.

It is difficult to answer the question whether land itself has the status of an independent resource and hence of an independent economic good or whether it should be considered as a vehicle providing important functions, such as storage capacity for water, minerals and oil, fertile soils, nature areas and recreational facilities and building lots for industry and housing. In most cases it is not land as such that is desired as an economic good but the resources, amenities and characteristics attached to the land. For example, one hectare of agricultural land in a dry area with no irrigation facilities and far away from an urban centre would cost only a fraction of the same amount of land in a fertile soil region close to a city. Here, it is the quality of the soil and the location that are considered valuable and not the actual plot of land. Correspondingly, pollution does not negatively affect the land itself but the resources, amenities and characteristics belonging to the land. For instance, intensive agricultural land use may cause nitrate pollution of groundwater or deterioration of soil quality but does not affect the plot of land as such.

A proposition that can unambiguously be put forward is that the use of land, regardless of the type of use, takes a central place in every economic activity, as several authors have pointed out. Randall and Castle (1985) describe land as "… *a fundamental organizing principle for human society* …" (p. 571), comprising distance, space and territory, legal rights and privileges and social relationships. Van Kooten (1993), citing Richardson, characterises land as a concept involving "… *the entire ecosystem, the natural order which embraces water, air and living things*" (p. 3). Mather (1986) defines land as "… *the basic natural resource*", that has been "…*man's habitat and living space*" and "… *a matter of life and death, of survival or starvation*" (p. 1).

This chapter deals with the economic characteristics of agricultural land. It provides some basic theoretical concepts needed to explain the reasons for policy intervention in agricultural land use. The main reasons for policy intervention include positive as well as negative externalities. Externalities occur through market failure, a situation in which the market mechanism does not lead to an efficient allocation of resources. Markets are defined as "… *institutions that organize the exchange of control of commodities, where the nature of the control is defined by property rights attached to the commodity*" (Gravelle and Rees, 1992, p. 513). The absence of well-defined property rights is hence an important cause of market failure[7]. Typically,

[7] Other causes of market failure are imperfect information, high information and/or transaction costs, and bargaining problems, i.e., if market participants cannot agree on how to share the gains from their exchange (Gravelle and Rees, 1992).

property rights are not well defined for environmental quality, such as clean air, open landscape, wildlife habitat and biodiversity. Thus it is not surprising that the concepts of externalities and missing property rights are at the core of environmental and resource economics (Van Kooten, 1993; Verhoef, 1999).

However, before going into the concept of externalities and missing property rights, we want to sketch out a situation without market failure. Section 3.2 will be concerned with the optimal allocation of land to different agricultural land uses. Two issues are of importance here. The first one is the actual identification of different agricultural land uses. For this exercise, we make use of the function-approach proposed by Hueting (1980). The second issue deals with the determination of land values and prices, because an optimal allocation of resources is derived from prices. With knowledge of the conditions in an optimal situation, we can then consider the factors causing a distortion of the optimal situation. The concepts of externalities and property rights are covered in Sections 3.3 and 3.4, respectively. Along with property rights, Section 3.4 deals with the associated concept of public and private goods. Applications A, B and C illustrate the concepts and theories discussed in this chapter. This chapter offers some conclusions in Section 3.5.

3.2 Allocation between Land Uses

Before going into the conditions for an efficient and optimal allocation of land between different uses (Subsection 3.2.3), the different uses or function of agricultural land have to be identified.[8] An appropriate method for this purpose is the function-approach proposed by Hueting (1980), who defines functions as possible uses of the environment by human beings. This approach is explained in Subsection 3.2.1. In order to determine an efficient and optimal allocation of resources, it is necessary to derive the economic returns, i.e., the factor earnings, for the competing uses. For this purpose, the concepts of land rent and values are described in Subsection 3.2.2.

3.2.1 Different functions of agricultural land

The fundamental role of land in economic activity and the diversity of uses make the economics of land use very complex. A systematic approach to investigating the economics of land resources is the *function* approach developed by Hueting (1980), in which functions are defined as possible uses of the environment (in this case agricultural land) by mankind. Functions have the capacity to satisfy the demands of individuals. In general, the term *function* can be regarded as a synonym for *uses*,

[8] In order to prevent misunderstandings, it is useful to emphasise again that, within the framework of this dissertation, we are mainly concerned with the different types of agricultural land use. Certainly, the allocation of land between, for instance, agricultural uses, urban uses and nature is another very interesting and relevant issue. It would, however, be beyond the scope of this dissertation to elaborate upon this issue in greater detail.

because functions contribute to satisfying people's individual utilities. In other words, functions are arguments of individual utility functions. However, Hueting points out that some vital functions of the environment do not belong to people's individual utility functions, because people are not aware of the importance of these functions for life on earth. In such a case, these functions do not fully coincide with utility. Figure 3.1 gives an overview of the different functions of agricultural land that have been identified by Slangen (1992) and Randall and Castle (1985).

AGRICULTURAL LAND

1) Productive function
- input for agricultural production

2) Ecological function
- habitat for many plant and animal species
- catchment of groundwater reservoirs
- connective elements of ecological network

3) Cultural function
- characteristic landscape and nature elements in rural areas that are recognised as cultural and historical heritage

4) Informative and educational function
- source of information for scientific research
- subject of education and teaching

5) Recreational function
- enjoyment of open landscape (biking, hiking, motorcycling, car touring)
- combines function 1-4
  1: hobby farming
  2-3: animal watching, viewing landscape
  4: scouting, educational vacations

6) Social function
- social status attached to land ownership
- distribution of wealth (and power) in society

Figure 3.1: Different functions of agricultural land

Traditionally, all six functions described in Figure 3.1 could be performed simultaneously, without competing with each other. Extensive and small-scale agricultural production, as it was performed before 1950, maintained, and in some cases even created, important cultural and ecological functions for agricultural land. The recreational function may be regarded as a combination of Functions 1) through 4), although the relative recreational value attached to Functions 1) through 4) may differ between individuals. Increasing agricultural intensification in the second half of the last century has caused increasing conflict and competition, especially between the productive function and the ecological and cultural functions of agricultural land. Specialisation and scaling-up of agricultural production required characteristic landscape features, such as hedgerows, small streams and ditches, to be removed, which, at the same time, destroyed important habitats for native plant and animal species (Bowler, 1986).

Agricultural intensification was accompanied by an increase in welfare and prosperity, changing needs and preferences within society. Especially in densely populated areas, notably north-western Europe and the East coast of the US, a growing demand for quietness, peacefulness and space in the countryside can be recognised. Overall, during the period in which attractive and characteristic landscape elements were removed from the countryside, public preferences for these elements rose (Slangen, 1992). Slangen describes this development as a classical illustration of supply and demand theory: a decrease in supply or an increase in scarcity of the attractive landscape elements leads to an increase in their value.

This case illustrates that the scarcity of a function can arise through competition with other functions. Competition between functions may occur along three dimensions: space, quantity and quality. The functions of agricultural land are not determined by the land itself but by the characteristics and environmental resources attached to the land. As long as a particular function does not generate externalities that influence the quality or quantity of a required environmental resource or spatially interfere with another function, there is no economic problem (Hueting, 1980).

However, once competition between functions occurs, the most desirable situation from a social welfare point of view is an optimal and efficient allocation[9] of land between the different functions. The determination of an optimal allocation between different function requires knowledge about the economic returns that each particular function generates. Land rents and values are discussed in the following subsection.

3.2.2 Concepts of land rent and values

Land Rents

The key concept in land economic theory and in determining the value of agricultural land is land rent. Land rent is the economic return that accrues to land in its current use. It is the determining factor for the allocation of land between competing functions and between individuals (Barlowe, 1972). It has to be noted that the meaning of land rent is slightly different from that of economic rent in general. Land rent can be defined as the residual economic surplus remaining after payment is made for total costs (Barlowe 1972). Classical economists, as well as the neoclassical economist Alfred Marshall, reserved the general term 'rent' exclusively for the returns to land. However, contemporary economic theory defines economic rent as a return to capital goods in a different way. Economic rent is nowadays defined as the part of the return to a production factor in excess of the amount required to call it into employment (Hirshleifer, 1980). The most important aspect determining the

[9] The difference between an optimal and an efficient allocation will be explained in Subsection 3.2.3.

difference between land rent and economic rent is land's supposed fixity in supply in absolute terms. This difference is illustrated in Figure 3.2.

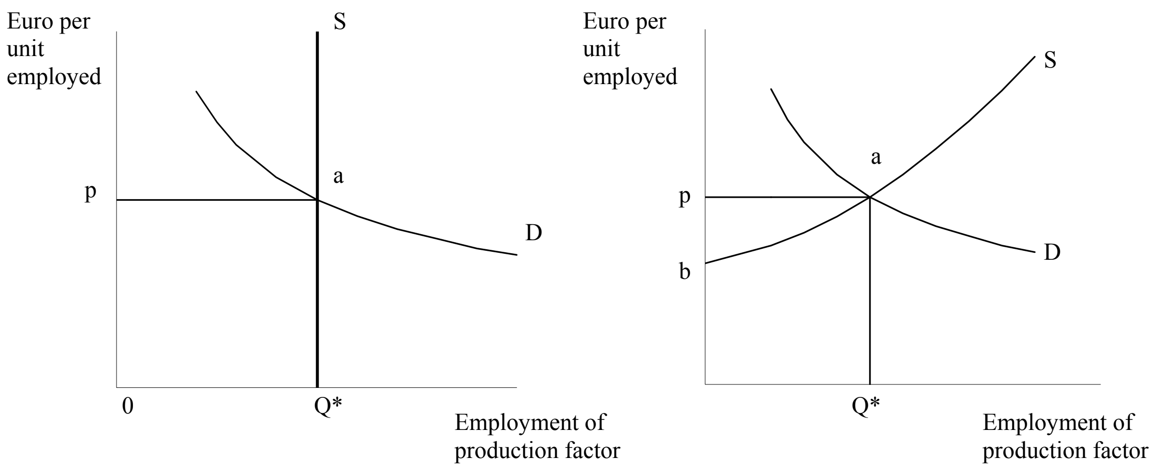

Figure 3.2: Land rent and economic rent
(Source: adapted from Hirshleifer, 1980)

The left panel shows rent, indicated by the rectangle 0-Q*-a-p, accruing to a production factor that is totally inelastic in supply, such as in the case of land that is supposed to be fixed in supply. In the case of a vertical supply curve, the amount Q^* of the production factor fixed in supply would be employed even at an infinitesimally small amount of rent (Hirshleifer, 1980). Furthermore, all employed units of the production factor that is fixed in supply earn the same amount of rent. The right panel shows the economic rent, indicated by the triangle b-a-p, accruing to a production factor that is not fixed in supply. With an upward sloping supply curve, the first units of the production factor employed earn higher rents than units employed later. In fact, the last unit employed does not earn any rent at all. Obviously, this fact is implied in the first-order condition for profit maximising input use that says that a production factor has to be employed until its price or cost equals its value of marginal product. Therefore, in the course of competition, economic rents will be bid away. They can thus be considered a short-run economic surplus that a production factor or an operator can earn due to unexpected demand or supply conditions (Van Kooten, 1993; Barlowe, 1972).

At this point, we must consider land's fixity in supply. It is certainly true that the absolute amount of land available in a region, country or the world is relatively fixed. However, land for a particular purpose, such as agriculture, can be created by, for example, drainage or irrigation. Alternatively, fertile land may be destroyed by, for example, overcropping or insufficient maintenance (Samuelson, 1980). In other words, if the price or the reward for land is high enough, more land will be provided, or if necessary, reclaimed from the sea, as in the Netherlands. On the other hand, if the reward for land is insufficient, it will be allowed to erode away (Hirshleifer, 1980). We will return to the question of supply fixity of land in Subsection 3.2.3.

Famous theories on land rent include those developed by David Ricardo (1772-1823) and Johann Heinrich von Thünen (1783-1850). Ricardo's theory is concerned with differences in fertility and quality of the soil. It mainly explains that spending the same amount of effort and expenses for, e.g., fertiliser and other inputs, on two fields of the same size may result in different yields if the soil quality and fertility of the two plots differ. Land hence produces higher rents with increasing soil quality, whereas land with some minimum quality level will remain unused. If output prices rise (or input prices fall) land that was previously unused will come into production. Ricardian rent is therefore solely concerned with land's agricultural production capability. It is also called 'differential rent', since varying rental values for different plots of land are caused by differences in soil quality (Howitt and Taylor, 1993).

Von Thünen's land rent theory is concerned with spatial location and distance to a central market place, such as a village or a city in the midst of a productive plain. Assuming uniform land quality in an isolated state, differences in land rent arise from transportation costs. Land use allocation, according to Von Thünen, can be described with concentric rings, of which the inner ring (the one closest to the market place) contains the most intensive usage, yielding the highest rent. In Von Thünen's time, the products produced in the inner ring would have been commodities like vegetables, dairy products and grain: these are commodities that require frequent and regular transportation to the central market place. The critical distance, at which production stops, is the point where unit transportation costs equal product price. (For further detail on the land rent theories of Ricardo, Von Thünen and others, see Van Kooten (1993), Randall and Castle (1985), Kruijt and Needham (1980), Barlowe (1972).

In the time of Ricardo and Von Thünen, land was mainly seen as a factor of production. Land rent could only be derived from commercial and profitable land use activities. Consumptive uses and considerations about protecting environmental amenities are not taken into account in classical models of land rent. In other words, wilderness areas were considered to be worthless (Randall and Castle, 1985). Nevertheless, as early as 1857, John Stewart Mill pointed out that land does not only serve as an input for agricultural and extractive uses but also as a provider of the intrinsic beauty of the countryside. He was also aware of the fact that land as a source of amenity values would gain more importance as material conditions in society improved (Perman et al., 1996).

The fundamental difference between agricultural production values and the amenity and environmental services of agricultural land, such as open space, wildlife habitat or cultural heritage, is the existence of a well-defined market for agricultural products and the lack of such a market for amenity and environmental services. Land use allocation left to the market would hence lead to a socially unsatisfactory supply of amenity and environmental services by agricultural land. It is generally assumed that extensive forms of agricultural land use improve or foster the provision of amenity and environmental services. Governmental subsidies and other compensatory payments for agricultural nature conservation are meant to enhance the competitiveness of extensive agricultural land uses. They may therefore be regarded as returns to land allocated to extensive land uses in addition to the returns generated by extensive agricultural production. In such a case, the government offers rent payments for the partial interest in land that is the public's interest in improving the provision of amenity and environmental services. In other words, the government purchases the property rights for a partial interest in land (Wiebe and Meinzen-Dick, 1998). Application B in the empirical part of this dissertation, the agri-environmental policy programmes in the EU, may be regarded as an example of this situation. The economic returns to land used in compliance with the agri-environmental policy regulation are made up of the production value of extensive land use and the payments of the policy programme. In Application A, the co-operative agreements between farmers and water supply companies, the water supply companies are interested in an extensification of agricultural land use. The water supply company may hence be interpreted as the purchaser of the property rights for a partial interest in land. The total amount of returns to a particular piece of land under agreement consists, on the one hand, of the production value generated under the restrictions of the co-operative agreements and, on the other hand, of the compensation payments the water supply companies offer to farmers who comply with the restrictions.

Land rents determine land values. The particular mechanism whereby land rents determine land values is described below.

Land Values

The introduction to this chapter mentions a number of characteristics of land that distinguish it from other capital goods. A characteristic not yet mentioned is that land is an indestructible capital asset providing a perpetual flow of income. In particular, the (present) value of land is determined by the discounted stream of future rents. In mathematical terms, this statement can be expressed as follows.

$$LV_t = \int_0^\infty E_t R_{t+k} e^{-kr} dk \tag{3.1}$$

where LV_t is the equilibrium land value at time t, R_{t+k} the land rent or the real residual returns to land at time $t+k$, E_t the expectation of returns to land conditional upon the information available at time t, and r the continuous real discount rate (Featherstone and Baker, 1987). Equation (3.1) represents the basic asset pricing or capitalisation model. The asset-pricing model emerged from finance and real estate theory, but it is also related to the net present value model used in natural resource economics (Randall and Castle, 1985).

Equation (3.1) shows that not only is land rent itself an important determinant for land values, but the expectation of land rent is an important determinant as well. Tegene and Kuchler (1991) stress the importance of the expectation formation mechanism for characterising market behaviour. The expectation formation mechanism determines the speed and size of adjustments in farmland values due to changing policies. In a situation where there is agricultural price support and direct government payments aimed at stabilising and protecting agricultural income, farmers are assumed to have optimistic expectations about future returns, which subsequently result in inflated land prices. If farmers are confronted with new information, they may have to adjust their expectations of future returns. Agricultural policy reforms with respect to market liberalisation, which imply uncertainty about future prices and income from the farmer's point of view, may cause more pessimistic expectations about future returns. The elasticity of land prices regarding expected farm revenues is therefore crucial for agricultural land price determination (Featherstone and Baker, 1988; Runge and Halbach, 1990 citing Hicks).

In the agricultural economic literature an extensive body of work on the determinants of farmland rents and values exists. Shi et al. (1997) divide the literature on agricultural land price determination into two broad categories. Studies in the first category use income from agricultural production as the major determinant for land rent and prices. Studies in the second category primarily use non-farm factors to explain variation in agricultural land prices. These studies are based on the hedonic pricing model, and frequently use variables such as the distance to urban centres or highways, population density, attractiveness for recreational activities, and/or land and soil characteristics. The focus of these studies ranges from the valuation of urbanisation and urban fringes (Stewart and Libby, 1998; Shi et al., 1997; Shonkwhiler and Reynolds, 1986; Chicoine, 1981; Dunford et al., 1985; Hushak, 1975; Clonts, 1970), to soil and site characteristics (Elad et al., 1994; Xu et al., 1993; Miranowski and Hammes, 1984), and erosion control and soil conservation (Palmquist and Danielson, 1989; King and Sinden, 1988; Ervin and Mill, 1985).

In Chapter 8, Application C investigates the capitalisation of agricultural income into land prices. This chapter discusses the determination of land prices in further detail.

3.2.3 Conditions for an optimal allocation

It has been stated that the total amount of land available to a region, country or the world is relatively fixed. However, the share of land allocated to particular uses is obviously not fixed. Agricultural land use may either be decreased or expanded according to the demand for agricultural land relative to other land uses. For example, the previous chapter (Section 2.3) illustrates that the share of agricultural land use in total land use in the European Union and the US has decreased, mainly due to increasing demand for urban areas and nature areas. Another example is the increase in intensive agricultural land use at the expense of extensive agricultural land use during the second half of the last century. What are the conditions for an optimal allocation of land between different uses?

Economics, in general, is concerned with the allocation of resources, and in particular with the *efficient* and *optimal* allocation of resources (Perman et al., 1996). A generally accepted criterion for describing an *efficient* state of the economy is the Pareto criterion introduced by the Italian economist Vilfredo Pareto in 1897. The Pareto criterion states that a particular state of the economy is efficient if it is not possible to make one or more persons better off without making at least one other person worse off. Accordingly, a state would be called inefficient if positive gains to any person were possible without losses to others. There are numerous potential Pareto-efficient states, all of them dependent on a certain initial distribution of factor endowments. The states can range from a state in which a single household receives all of the national income whereas all other households receive nothing, to a state in which all households receive equal income (Varian, 1992).

The Pareto criterion is, however, not sufficient to ensure the maximisation of social welfare, which requires an observable social welfare function. An optimal allocation of resources is defined as an efficient resource allocation that simultaneously maximises the social welfare function. An optimal allocation is therefore always efficient. An efficient allocation is, however, not necessarily optimal (Perman et al., 1996). A social welfare function generally aggregates the individual utility functions of the members of a society. The actual form of the function may differ with respect to the weights attached to particular individuals or groups of individuals, which are determined by the social decision-maker's preferences about how to trade off the utilities of different individuals (Varian, 1992). It is mainly a question of equity and justice, and it would go beyond the scope of this dissertation to elaborate on these issues in further detail.

A socially optimal allocation is obtained when the aggregated social returns to land generated by the different uses are maximised. The condition for rent maximisation requires that the land be allocated among different uses until the rent of the marginal unit of land is equal for each use (Hartwick and Olewiler, 1997). How do we allocate land between intensive and extensive agricultural use in a socially optimal way? Assuming that intensive agricultural land use generates negative externalities and extensive agricultural land use positive ones, the 'values' of the externalities are, along with the agricultural production value, decisive for the optimal allocation between intensive and extensive agricultural land use. The following section starts with some generalisations about externalities. Subsequently, it takes up the question of socially optimal allocation by presenting a simplified model incorporating negative and positive externalities.

3.3 Externalities

3.3.1 Pecuniary versus technological externalities

The economic literature broadly distinguishes between two types of externalities: *technological* externalities and *pecuniary* externalities. Pecuniary externalities are present if an individual's activity level affects the financial circumstances of another individual. They are, however, not necessarily responsible for a misallocation of resources (Baumol and Oates, 1975). Pecuniary externalities may occur due to changes in relative input or output prices in a certain market. For instance, a new firm that is, due to improved production technology, able to produce a certain commodity at lower costs than incumbent firms causes a decrease in the commodity's output price. Decreasing output prices are negative pecuniary externalities to incumbent firms, since they affect their revenues. However, this process is just the functioning of a competitive market and hence, by definition, efficiency enhancing. In short, in order to attain an efficient allocation of resources, technological externalities need to be taken into account and pecuniary externalities need to be ignored (Holcombe and Sobel, 2001).

Nevertheless, governmental policy often aims at preventing pecuniary externalities, i.e., protecting particular groups in society from pecuniary losses, such as decreasing resource and asset values. Subsidies to farmers, trade barriers, tariffs and quotas protecting domestic agricultural production from foreign competition are prominent examples of governmental actions taken to compensate for the pecuniary losses a competitive market would impose on farmers (Holcombe and Sobel, 2001). Subsidies of a particular type of farming, e.g., wheat production, may in turn generate pecuniary externalities. The subsidies may increase the demand for agricultural land for wheat production, which may lead to a rise in land prices. Farmers producing other types of agricultural goods would then face higher production costs due to increased rents and prices for agricultural land. Therefore, the wheat farmer's increased demand for land would affect the value of the monetary variables, rather than the value of the physical variables such as deterioration of soil quality. Physical variables are affected by technological externalities.

Environmental economics mainly deals with technological externalities. The common definition of externalities states that an externality occurs whenever the production or consumption decision of one agent in the economy, such as a firm or a household, affects the welfare of another agent in an unintended way, and when, additionally, the affected party does not receive any compensation from the agent producing the externality (Perman et al., 1996). Equation (3.2) expresses technological externalities in mathematical terms. It shows the production function of a Firm A that produces output q_A using inputs (a_1, a_2, …).

$$q_A = f(a_1, a_2, ...; q_B, b_1, b_2, ...) \tag{3.2}$$

The terms on the right hand side of the semicolon show the level of output and input usage of Firm B. A technological externality exists if any of the terms on the right hand side of the semicolon have a non-zero effect on the physical output level of firm A, holding Firm A's level of input usage constant. Consider Application A in the empirical part of this dissertation, which considers the conflict between farmers and water suppliers concerning groundwater quality. The water supply company, represented in Equation (3.2) by Firm A, produces drinking water of a certain quality level using a number of inputs, such as groundwater, energy and pumping facilities. The actions of farmers located in the same area as the water supplier (represented by Firm B in Equation (3.2)) affect the production of drinking water through agricultural inputs, such as organic and mineral fertiliser. The quality of the drinking water changes due to nitrate pollution in groundwater. The original groundwater quality can only be reached if the water supplier uses additional inputs in form of purification facilities.

In summary, the fundamental difference between technological and pecuniary externalities is that technological externalities modify the functional relationship between the quantities of resources used as inputs and the quantity or quality of the physical output. Pecuniary externalities 'only' influence the financial situation of an affected individual. They do not involve any change in the efficiency of the production process when regarded as a transformation of inputs into physical outputs and/or utility levels of the members of the economy (Baumol and Oates, 1975).

3.3.2 Positive versus negative externalities

A basic classification of technological externalities is in terms of divisions between positive and negative and between production and consumption externalities. The examples in the following table illustrate this classification system (adapted from Perman et al. (1996)).

Table 3.1: A basic classification of technological externalities

	Production	**Consumption**
Positive	*Fruit tree plantations and apiaries:* The fruit tree farmer benefits from the proximity of an apiarist whose bees pollinate the blossoms of the fruit trees.	*Garden viewing:* The neighbour of a garden friend enjoys the nice flowers in the adjacent garden.
Negative	*Groundwater pollution from agriculture:* Due to overfertilisation, residuals of mineral fertiliser and manure are washed out into groundwater resources.	*Pleasure Hunting:* Unregulated pleasure hunting distorts wildlife and may even lead to a loss of animal species.

It is interesting to note that the distinction between positive and negative externalities from agriculture is often ambiguous. For example, the drainage of land in

Europe and North America has certainly destroyed major parts of the original bogs and wetlands, which would commonly be considered a negative externality. Yet, drainage has also played an important role in eliminating malaria in these regions, a positive effect with respect to public health (Shortle and Abler, 1999). An important concept for determining whether an externality is positive or negative is the concept of the reference point (Bromley and Hodge, 1990). A reference point is defined as the level of environmental quality society believes should exist as a minimum condition for health (Hanley et al., 1998). According to Bromley and Hodge (1990), the reference point specifies a particular allocation of property rights, which implies the level of responsibility landowners have to take for their land use decision-making. We will come back to the concept of the reference point in Subsection 3.4.2 when dealing with property rights.

This dissertation mainly deals with the left column of Table 3.1, the externalities arising from agricultural production. The externalities dealt with in Application A, the co-operative agreement between farmers and water supply companies, have been identified above as technological externalities of agricultural production. The welfare of the water supply company is negatively affected by the activities of the farmers, who are responsible for applying nitrogen-containing fertiliser to agricultural land. The negative welfare effect arises through the increasing costs the water supply company faces in complying with the current legal restrictions on nitrate content in drinking water.

Furthermore, negative technological externalities may occur as a result of inflated land prices, an issue that is addressed in Application C, the capitalisation of agricultural income into land prices. Since land is one of the most important production factors and, additionally, the production factor with the least elastic supply, large parts of agricultural support are capitalised into land values. As a result, land rents and values are relatively high. At the same time, prices of fertiliser and pesticides have decreased significantly relative to agricultural land prices and rents (recall Figure 2.3 in the previous chapter). Land has become relatively more expensive, leading to a substitution between land and other inputs, such as fertiliser and pesticides. Some authors state that, given the fact that fertiliser and pesticides are substitutes for land, the reduction of agricultural support will lead to a decapitalisation of support payments from land values and hence encourage the adoption of low-input systems (Daberkow and Reichelderfer, 1988). The actual response of farmers to a change in relative factor prices depends, however, on the elasticity of substitution between land and other inputs (Potter and Goodwin, 1998).

Application B, dealing with agri-environmental policy programmes in the EU, focuses on the positive environmental externalities of extensive agricultural land use. Agricultural land use that is consistent with the requirements of environmental protection and that maintains characteristic landscapes in the countryside is considered welfare-enhancing for society.

3.3.3 Optimal allocation of externalities

We turn once again to the question of the optimal allocation of resources, considering the optimal allocation of externalities in particular. The efficient allocation between different uses of agricultural land is illustrated in the following simplified model (adapted from Lopez et al., 1994). Consider two different uses of agricultural land: land in intensive agricultural production, AL_{int}, and land in extensive agricultural production, AL_{ext}. It is assumed that land allocated to intensive agricultural production generates benefits, B_{int}, including private benefits, PB_{int}, and negative externalities, NE. Land in extensive agricultural production generates benefits B_{ext} including private benefits, PB_{ext}, and positive externalities, PE. Total land in agricultural production, AL, is hence composed of land in extensive use and land in intensive use. Total social benefit, SB, is composed of benefits from extensive and intensive land use. In mathematical terms:

Benefits from extensive land use equal:

$$B_{ext} = PB_{ext} + PE, \tag{3.3}$$

where $PB_{ext} = f_1(AL_{ext})$, $PE = f_2(AL_{ext})$, $\dfrac{\partial f_i}{\partial AL_{ext}} > 0$, $i = 1,2$

Benefits from intensive land use equal:

$$B_{int} = PB_{int} + NE, \tag{3.4}$$

where $PB_{int} = f_3(AL_{int})$, $NE = f_4(AL_{int})$, $\dfrac{\partial f_i}{\partial AL_{\text{int}}} > 0$, $i = 3,4$

Total social benefits are equal to:

$$SB = B_{ext} + B_{int} \tag{3.5}$$

A public policy planner whose intention is to maximise social benefits would have to solve the following maximisation problem.

$$\max SB = B_{ext} + B_{int}, \quad \text{s.t. } AL = AL_{int} + AL_{ext} \tag{3.6}$$

The Lagrangian to this problem takes the following form:

$$L = PB_{ext} + PE + PB_{int} + NE + r(AL - AL_{ext} - AL_{int}), \tag{3.7}$$

with the following first order conditions:

$$\frac{\partial L}{\partial AL_{ext}} = \frac{\partial PB_{ext}}{\partial AL_{ext}} + \frac{\partial PE}{\partial AL_{ext}} - r = 0\,, \tag{3.8}$$

$$\frac{\partial L}{\partial AL_{int}} = \frac{\partial PB_{int}}{\partial AL_{int}} - \frac{\partial NE}{\partial AL_{int}} - r = 0\,, \tag{3.9}$$

where r represents the shadow price for land, i.e., the rent that emerges as a solution to the optimisation problem (Perman et al. 1996).

Solving both equations for r and rearranging gives:

$$\frac{\partial PB_{ext}}{\partial AL_{ext}} + \frac{\partial PE}{\partial AL_{ext}} = \frac{\partial PB_{\text{int}}}{\partial AL_{\text{int}}} + \frac{\partial NE}{\partial AL_{\text{int}}} \tag{3.10}$$

Equation (3.10) implies the following about a socially optimal allocation of agricultural land use between extensive and intensive uses. The marginal private benefits of extensive agricultural land use plus the marginal positive externalities have to be equal to the marginal private benefits of intensive agricultural land use plus (minus) the marginal negative externalities. Marginal positive benefits reflect marginal social benefits and marginal negative externalities reflect marginal social costs. An efficient allocation of externalities requires that marginal social costs and benefits be equal, i.e., marginal positive externalities should match marginal negative externalities. Panel (a) and (b) in Figure 3.3 depict the problem discussed here.

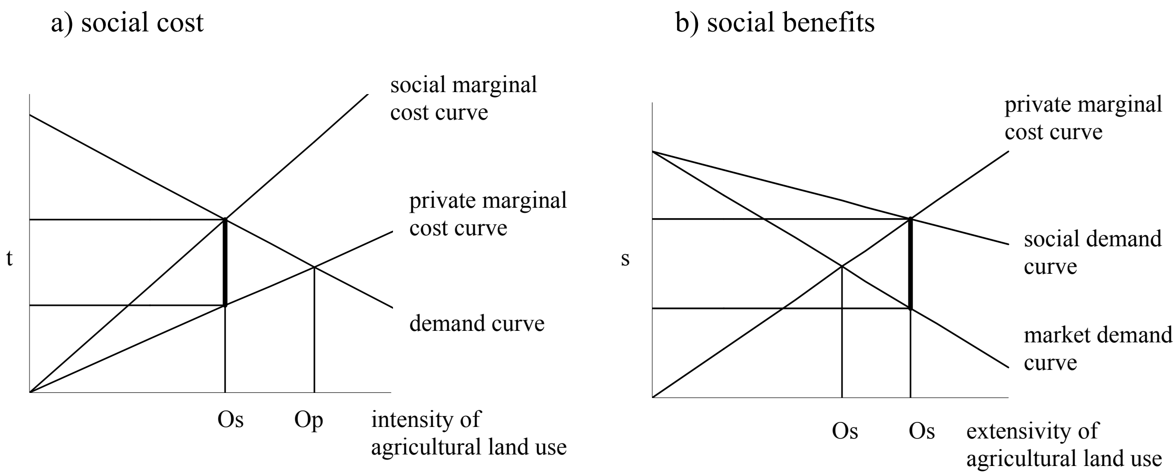

Figure 3.3: Social cost/benefits of intensive/extensive agricultural land use

Panel (a) shows the private and marginal social cost curve of intensive agricultural land use. Private producers do not take into account the negative externalities they generate by intensively using agricultural land. Since society has to bear the costs caused by the negative externalities, the social marginal costs of intensive agricultural production are obviously higher than the private marginal costs. The demand for agricultural land for intensive production is hence higher in the private optimum, O_p, than in the social optimum, O_s. In order to reduce the private demand for intensively used agricultural land to the social optimum, O_s, a tax represented by the distance *t* would need to be imposed on intensive agricultural land use. Panel (b) shows the social and market or private demand curves for extensively used agricultural land. Private producers generate beneficial externalities through the extensive use of agricultural land. Since the private producers are not being rewarded for extensively using agricultural land, the demand for extensively used agricultural land is higher in the social optimum, O_s, than in the private optimum, O_p. In order to increase private demand for extensively used agricultural land, a subsidy represented by the distance *s* would need to be introduced. In this simple model, an efficient allocation of agricultural land between intensive and extensive land use could hence be achieved by using the taxes collected from intensive producer to subsidise extensive producers. In such a case, intensively used agricultural land of the amount O_s - O_p would be reallocated to extensively used agricultural land.

Taxes or subsidies designed to mitigate the negative or positive effects of externalities in the way described above are called Pigouvian or corrective taxes. Under the condition that marginal costs and benefits of particular forms of land use are known, the application of Pigouvian or corrective taxes and subsidies may indeed lead to a Pareto-efficient allocation of resources (Stiglitz, 1986). However, in a real-world situation, the determination of marginal costs and benefits and hence of the optimal amount of taxes and subsidies involves a number of problems. A major point of concern is the actual monetary valuation of negative and positive externalities. A rather straightforward way to measure negative externalities is on the basis of the costs involved in ‘cleaning-up’ the negative externalities. There are, however, other types of negative externalities that are not easily valued. What about the simplification of the landscape due to specialisation and the scaling up of agricultural production, which reduces the amount of local wildlife habitat and infringes upon scenic views of the landscape? Or, how should the positive externalities attached to extensively used grassland that provides as habitat for breeding birds and other wildlife be valued? These externalities share the character of public goods for which an ordinary price system is not available and which therefore do not have a precise market value (Baumol and Oates, 1975). Approaches to this problem have been elaborated in the literature on non-market valuation of environmental goods. And, as mentioned in Section 2.3 of the previous chapter, quite a large amount of research is available on the non-market valuation of (extensive) agricultural land. We will come back to the issue of taxation/subsidisation in Chapter 4.

3.4 Public Goods, Private Goods and Property Rights

3.4.1 Public versus private goods

In the case of environmental externalities, we can basically distinguish between private goods and public goods. Two properties that are important for the categorisation of goods are *rivalry* and *excludability*. A rival good is a good for which consumption by one person reduces the amount available to another person, such as an apple or a cup of coffee (Varian, 1992). Once an apple is consumed by one person, it can no longer be consumed by another person. In the literature, a rival good is also called a divisible or depletable good (Perman et al., 1996) or a diminishable good (Varian, 1992). A good is excludable if the owner of the good can prevent consumption of the good by other people. Private goods are typically rival and excludable.

Pure public goods are generally characterised by *non-rivalry* and *non-excludability*, although definitions in the literature are not always consistent. The non-rivalry of a public good becomes obvious when the consumption of such a good does not prevent other people from consuming the same good. For example, the recreational services of a nature area can be enjoyed by many individuals at the same time. In other words, an additional consumer of the service provided by a nature area does not require an additional unit of the nature area, i.e., the marginal costs of providing the public good are zero. The same counts for other environmental services, such as, clean air, attractive landscape and scenic views. In a competitive market, where private producers price their products equal to marginal costs, the supply of public goods would hence result in zero returns to the private producer. This implies that a purely competitive market fails to achieve an optimal supply of public goods (Randall, 1972).

Non-excludability may occur for two reasons. First, a good is non-excludable if no person has the legal right to prevent another person from consuming the good, i.e., if nobody possesses exclusive property rights for the good. Second, regardless of whether or not property rights are assigned, excluding people from consuming the good may be infeasible due to technical impracticability or intolerably high costs (Perman et al., 1996).

In addition to the environmental services described above, lighthouses, national defence systems, highways and bridges are prominent examples of public goods. Whereas lighthouses and national defence are indeed pure public goods, i.e., non-rival and non-excludable, highways and bridges are often noted as mixed public goods. Mixed public goods are neither purely rival nor purely excludable and can be viewed as an intermediate case between purely public and purely private goods (Boadway and Bruce, 1984). Highways and bridges are, in general, non-excludable but are subject to congestion, which means that they are not non-rival. In fact, nature areas may also be, to some extent, considered as rival goods, since an increasing number of visitors may be regarded as causing a decrease in their quality. Examples of mixed public goods that are non-rival (at least if the overall rate of usage does not exceed the threshold of congestion) but excludable are: coded TV broadcasts, rock concerts and swimming pools (Wills, 1997). This category of goods is also called club goods. Figure 3.4 summarises the categorisation of goods.

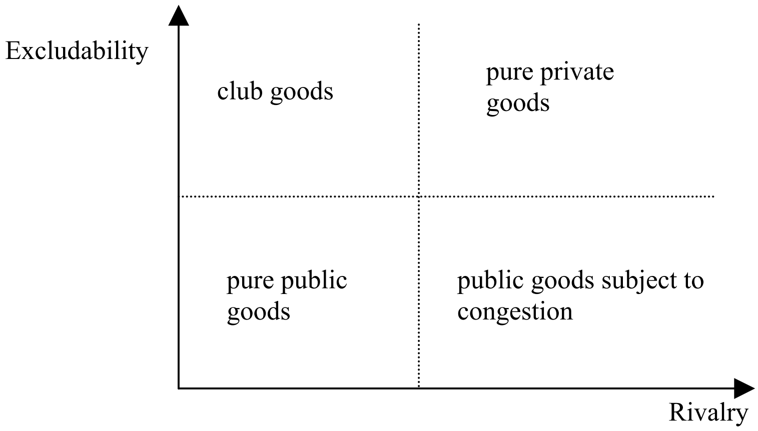

Figure 3.4: Categorisation of goods along their degree of rivalry and excludability

Plots of agricultural land are private property owned by farmers and/or other landowners. Nevertheless, agricultural landscape, which is an aggregation of the individual plots of land, and all its scenic beauty and environmental amenities, is considered a public good.

Having posited that many environmental services have public good characteristics, we may accordingly propose that environmental pollution possesses the characteristics of a public 'bad'. For example, the harm caused by air or water pollution to one individual does not reduce the harm suffered by another individual. Environmental pollution is in general non-rival and non-excludable. According to this reasoning, the technologies and means to reduce environmental pollution are also non-rival and non-excludable and hence may be regarded as public goods (Wills, 1997). It is therefore justifiable that they be financed by the public budget.

3.4.2 Property rights

The concept of property rights is by far the most important and most fundamental institutional factor that determines the ownership and use of resources such as land (Barlowe, 1972). It is also responsible for the distribution of costs and benefits generated by land within a society (Miranowski and Cochran, 1993). It should be stressed that ownership of land implies the ownership of a bundle of legally-defined user rights, and not the ownership of the object as such. Dales (1992), citing Coase, points out that "…*it is rights, never objects, that are owned, and the rights themselves are limited by law*".

The extent to which property rights over land are limited by law differs according to the characteristics of the good and the prevailing policy regime. A strictly defined private good implies the existence of well-defined property rights. A market for such a good is likely to exist and an efficient allocation of resources without government intervention may be reached (Perman et al., 1996). In such a situation, there may be no or only very few legal limitations on rights to use this good. The fact that a market for agricultural land as a production factor exists indicates the private good characteristics of individual plots of land. However, as mentioned above, the aggregation of individual plots of land shapes the agricultural landscape, which has been characterised as a public good. There are no private property rights for public goods and therefore, it is the responsibility of the government to guarantee the provision of these goods. Furthermore, the occurrence of negative as well as positive externalities due to agricultural land use indicates the misallocation of land uses. In such a situation, the right to use land needs to be limited by law.

The government can limit private property rights to use land by means of various policy regimes, meaning that it can determine the use of land to some extent. In light of the description of property rights given above, government intervention in private land use implies the reallocation of a certain part of the bundle of property rights to society. Consider, for example, a law that obliges farmers to reinstall hedgerows on their agricultural land. Hedgerows improve wildlife habitat, prevent soil erosion and are essential for a scenic landscape. They may thus be regarded as a public good. By mandating that farmers reinstall hedgerows, the government determines the scale of plots, which implies that it takes away the right to determine the most efficient scale for the plots privately.

Different policy regimes are associated with different forms of property rights allocation. Consider Application A, the co-operative agreement between farmers and water supply companies. The co-operative agreements offered by the water supply companies include payments to farmers to encourage the adoption of environmentally friendly practices in order to reduce the emission of nitrate into groundwater. The fact that farmers receive compensation for restricting their use of land indicates that property rights are fully assigned to farmers. Moreover, the ‘agricultural’ property right in land seems to include the right to use the underlying groundwater resources as a sink, although groundwater is considered a common property resource, for which property rights are not well-defined.

Subsidising farmers to reduce nitrate emissions presumes that farmers produce a positive environmental externality, namely the improvement of groundwater quality, instead of a negative production externality as stated above. The concept of a reference point has been introduced above as an important concept for differentiating between positive and negative externalities. Recalling Hanley et al.’s (1998) definition of a reference point, it can be concluded that farmers produce positive environmental externalities if society considers the current level of groundwater quality to be above the reference level. However, the implementation and maintenance of particular directives prescribing a maximum legal threshold for nitrate in drinking water implies that the current level of groundwater quality is in fact below the desired reference level. This is consistent with the perception that farmers produce environmental costs rather than benefits. This does, however, not correspond to reality, where subsidising farmers to reduce nitrate emission is the rule rather than the exception.

A similar situation can be observed as in Application B, the agri-environmental policy programmes in the European Union. The main instruments of these policies are compensation and incentive payments to farmers to encourage environmentally sound agricultural land use. The property rights for agricultural land are therefore clearly assigned to the farmers.

3.5 Conclusions

This chapter has highlighted the economic characteristics of agricultural land and the consequences of these particular characteristics for the environment. Although land as a particular form of capital has often been neglected by neoclassical economists, it has a number of characteristics that distinguish it from other capital goods. The most important characteristic is certainly the heterogeneity of land, caused by, for example, soil quality or location, which determines its suitability for particular production processes. Heterogeneity of land is, furthermore, determined by other important resources, such as water or minerals, and the environmental amenities attached to a certain plot of land. In fact, most of the environmental amenities attached to land have public good characteristics for which private property rights are not defined. This situation leads to an undersupply of positive externalities, i.e., public goods, and an oversupply of negative externalities, i.e., public 'bads'. As long as there is no market for the unpriced amenities of land, public intervention is justifiable in order to stimulate the production of positive externalities and suppress the production of negative ones.

Agricultural policy reforms are, among other things, concerned with reducing negative externalities and promoting positive externalities from agricultural land use. Imposing restrictions on the use of agricultural land use corresponds to annexing part of the property rights for the use of agricultural land, assuming that in the original situation the property rights had been fully allocated to the farmers. However, in many cases imposed restrictions are accompanied by compensation payments. In these cases, part of the property rights are, in fact, purchased rather than annexed.

Farmers that are rewarded for the production of positive environmental externalities often complain about losing their feeling of being self-employed, or, casually speaking, of being the 'boss in their own yard'. They have the feeling of getting paid for being a public 'gardener', who is dependent on direct financial support from the government. Instead, they prefer to earn their living by selling their products at a reasonable price. Some probably realise that their earnings from the production of agricultural goods were also dependent on financial support from the government. Or should this type of financial support be regarded as a reward for another positive externality, namely, the knowledge that the national food supply, in quantitative terms, is secure? The following chapter elaborates details of agricultural and environmental policy- making.

CHAPTER 4

AGRICULTURAL AND ENVIRONMENTAL POLICY-MAKING

4.1 Introduction

Policy-making is a complex, interactive and continuously ongoing process. It is complex because many different agencies on various levels of government introduce policies that either directly or indirectly influence each particular policy issue. It is interactive because different policy options need to be negotiated, leading to trade-offs and compromises that open up new opportunities not initially considered. It is a continuously ongoing process since the implementation of one policy almost always generates new problems for the policy agenda (Lindblom and Woodhouse, 1993).

Along with ensuring national self-sufficiency in food products, traditional supportive agricultural policy is meant to tackle another problem intrinsic to the agricultural sector, the chronic farm income problem. On the demand side, the income inelastic nature of food demand causes the agricultural sector's growth rate to lag behind the economic growth rates of other sectors in the economy. Consequently, farm income will rise less than income in other sectors. On the supply side, the temporal lag between price signals influencing production decisions and output response is rather large. Original market conditions may have changed, which may lead to exaggerated volatility in market prices. Accordingly, farm income is variable and unstable (Kay, 1998). Additionally, rises in agricultural productivity brought about by technical innovations have led to decreasing food prices.[10] Policy instruments, such as price support and price stabilisation, are applied to overcome the chronic farm income problem. Agricultural policy has hence solved one group's problem, that of the farmers. However, because of its well-known adverse external effect on the environment, this solution turned out to create welfare losses for another group, the environmentalists.

The decreasing importance of the agricultural sector and changing consumer preferences, as reported in earlier chapters of this dissertation, have shifted the emphasis of agricultural policies in many industrialised countries. Although the viability of the agricultural and rural community is still an important objective for the reformed policies, nature conservation and the protection of environmental amenities

[10] In a study on technical progress and structural change in agriculture in OECD countries, Alston et al. (1995) point out that the prices farmers receive for their products have been falling, not only in real terms, but also relative to the prices farmers pay for their inputs.

receive considerably more attention than they did before the reforms. Overall, as for many other fields of policy, the guiding principle for agricultural policy should be sustainable development and sustainable agricultural land use.

According to the World Commission for Environment and Development (WCED, 1987), sustainable development requires the integration of environmental objectives with more general financial, economic and industrial policies. It is supposed that this integration helps to overcome the failure of environmental policies as it was experienced in many developed countries when environmental policy making was first initiated. The policy failure has become visible in the gap between the environmental policy objectives that were aspired to, on the one hand, and the actual realisation of these objectives, on the other hand. Verbruggen (1994) argues that policy failure is mainly due to an instrument crisis, caused by a) inefficient and ineffective application of environmental policy instruments, b) failure to apply environmental policy instruments at the optimal level of government (the local, regional, national or international level) and c) inconsistent policy-making and insufficient coordination between different levels of government and different sectors in the economy. The causes for the instrument crises are, in fact, institutional failures. A proper institutional framework is hence a necessary condition for the application of policy instruments.

Cause c) becomes especially apparent in the agricultural sector. Agricultural and environmental policies affecting agricultural land use are often contradictory. Examples of such contradictions include set-asides of productive farmland in order to reduce commodity surpluses on the one hand and subsidising irrigation water to increase productivity on the other hand. Likewise, subsidising farmers who adopt soil conservation practices while supporting prices of highly erosive crops seems incongruent (Reichelderfer and Randall, 1993). Furthermore, the agri-environmental policy of the European Union (Regulation 2078/92) seems to be poorly integrated with other Common Agricultural Policies (CAP). Among others, this becomes obvious in observing the regular CAP programme’s maize premium, which is in many cases higher than the grassland premium under the agri-environmental policy (Buller, 2000).

The aim of this chapter is to shed light on agricultural and environmental policy-making processes. The discussion above has mentioned a number of issues that will be further elaborated upon in the remainder of this chapter. Section 4.2 provides a definition of the concept of sustainability as the overall policy goal and elaborates upon the subject of indicators as tools for measuring sustainable development. The structure of the policy-making process and the respective actors involved in it are the focus of Section 4.3. Section 4.4 deals with the different levels of government that may be involved in different stages of the policy-making process. Section 4.5 discusses different types of policy instruments.

4.2 Agricultural Sustainability

4.2.1 Defining the policy goal

Ever since the announcement of Agenda 21, the Rio Declaration On Environment And Development in 1992, the notion of sustainability has been required to be the guiding concept for policy-making in all economic sectors and on all administrative levels. *Sustainable development* and *sustainability* have become catchwords for policy advisors and policy makers propagating bills that are supposed to be beneficial to the environment and society. Despite the popularity of the term *sustainability*, or probably because of it, the actual meaning of the term remains vague. In the literature, many different definitions of sustainability can be found (see, e.g., Perman et al., 1996), but the most commonly cited is the Brundtland Commision's definition: "*Sustainable development is development that meets the needs of the present without comprising the ability of future generations to meet their own*" (WCED, 1987, p. 43). It becomes obvious from this definition that intergenerational equity, i.e., non-declining per capita human well-being over time (Pearce and Atkinson, 1995), is a core element of the concept of sustainability.

However, the Brundtland definition, as well as many other writings on sustainability, does not answer to this important question: "What do we want to sustain?" There are at least three different dimensions along which sustainable development can be defined (Tisdell, 1997), namely:

a) ecological sustainability, which means maintaining ecological processes;
b) economic sustainability, describing the economic feasibility of development; and
c) social sustainability, requiring the social acceptability of development.

With respect to agriculture, the ecological dimension comprises the conditions for plant growth and animal breeding, such as soil fertility, climate, and geological circumstances. Ecological sustainability guarantees the preservation or even improvement of the current quality of environmental services responsible for the productivity of agricultural land. The economic dimension reflects agriculture as an enterprise on the farm level and as an economic sector on local, regional, national and supranational levels. Economic agricultural sustainability describes the long-term economic viability of a farm or the agricultural sector in general. The social dimension includes a variety of issues, ranging from the quality and security of the food supply, the distribution of income within the agricultural sector and between other sectors, the efficiency and fairness of the distribution systems for food and agricultural production factors, to communal and social cohesion in rural areas and working conditions in the agricultural sector (Smith and McDonald, 1998; Conway, 1987; Douglass, 1984).

Obviously, *full* sustainable development should take into account all three dimensions in an integrated manner, though in many cases within policy only one dimension is considered as a justification for sustainable development. Certainly, the relative importance of the various characteristics included in the three dimensions differs on the spatial and administrative levels. For example, whereas on the farm level, production costs and economic viability may be the leading principles, sufficiency of food supply and income distribution may be more important on a national level (Smith and McDonald, 1998). It goes without saying that a policy for sustainable development on a certain administrative level needs to be in agreement with policies on other administrative levels. Sustainability would need to be attained on all administrative levels, i.e., on local, regional, national, international and global scales.

For agricultural sustainability in particular, numerous definitions can be found in the literature (for an overview, see Hansen, 1996). Ikerd (cited by Rigby and Cáceres, 2001) gives an understandable definition: Sustainable agriculture is "... *capable of maintaining its productivity and usefulness to society over the long run...it must be environmentally sound, resource-conserving, economically viable, commercially competitive and socially supportive*". Obviously, this definition includes the three dimensions noted above.

Conventional agricultural production is often associated with the depletion of non-renewable resources, soil degradation, negative health and environmental effects from agricultural chemicals, inequity, declining rural communities, loss of food quality and a decrease in the number of farms, along with an increase in their size. It is therefore often perceived as unsustainable (Hansen, 1996). Sustainable agriculture is often regarded as an alternative to conventional agriculture and its characteristics are mainly described as the opposite of those of conventional agriculture (Beus and Dunlap, 1990; Hill and MacRae, 1988).

However, Hansen (1996) warns that stigmatising conventional agriculture for being unsustainable and alternative agriculture[11] for being sustainable may lead to a distorted view of conventional agriculture. For example, Trewavas (2001) points out that *integrated farm management*, a conventional farming strategy for retaining the benefits of modern agricultural technology while minimising the environmental problems, may lead to an equal reduction of environmental pressure as that which organic farming produces. In such a case, approaches that enhance sustainability may be ignored or rejected because of their association with conventional agricultural methods. Furthermore, alternative agriculture often puts more emphasis on the ecological dimension of sustainable development. It is often criticised for neglecting the social dimension, i.e., meeting the needs of growing populations, an issue especially important in developing countries.

The relative weights of the three dimensions of sustainability in policy-making also differ over time. Current levels of agricultural support in most developed

[11] Alternative agriculture comprises several alternative approaches, such as organic farming, regenerative agriculture, ecological agriculture, biodynamic agriculture, permaculture, natural farming and low-input agriculture (Beus and Dunlap, 1990).

countries are said to be unsustainable, especially with respect to the macro-economic and ecological dimensions. Expenses for agricultural support measures put an increasing financial burden on the public budget. A good example is the European Union and its prospective expansion to the East. An enlargement of the EU would not allow the continuation of the same level of agricultural support as is employed in the current Member States. In other words, the financial expenses cannot be 'sustained'. With respect to the ecological dimension, agricultural support levels are supposed to stimulate farming practices that put increasing pressure on the environment and that are to a large extent dependent on non-renewable and off-farm resources. A continuation of these farming practices is said to be unsustainable. However, these policies mainly evolved after the Second World War, when security of the food supply was the most important objective on the policy agenda. In those days, ecological considerations may not have been considered important and may not have been accepted by societies that had experienced periods of famine during the last years of the Second World War.

Having discussed the issues of sustainable development and agricultural sustainability, we recognise that the two terms cannot be properly described within a single definition. In response, the literature on sustainable development has come up with the idea of sustainability indicators (Pannell and Glenn, 2000). Sustainability indicators measure and evaluate a certain policy option for its suitability in creating sustainable development (Pearce, 1999). They are described in further detail in the following subsection.

4.2.2 Measuring sustainability

Although in the context of this dissertation we are mainly interested in measuring agricultural sustainability, we will first look at some general issues of sustainability measurement. An important factor that needs to be considered is the concept of weak versus strong sustainability. The main difference between weak and strong sustainability lies in the assumption that different types of capital may be considered substitutes. The literature distinguishes between four types of capital (Tisdell, 1997; Serageldin, 1996; Perman et al., 1996):

a) *Natural capital* — the naturally provided stock of assets, such as water systems, soil, atmosphere, wetlands, crude oil and gas, minerals, forests, fish and other stocks of biomass.

b) *Physical capital* — capital that is usually considered in economic accounts, such as machines, plants, buildings and infrastructure.

c) *Human capital* — the stock of knowledge and learned skills embodied in particular individuals.

d) *Social capital* — institutional and cultural basis for the functioning of society; the stock of knowledge that is not embodied in particular individuals.

The combination of physical, human and social capital may be described as man-made capital. Weak sustainability assumes that there are substitution possibilities between all four types of capital. As long as the total amount of capital is kept constant, weak sustainability is attained, regardless of the composition of total capital. Strong sustainability requires that natural capital remain constant (Serageldin, 1996). Weak sustainability is criticised for not taking into account essential life-supporting functions of the ecosystem (Pearce and Atkinson, 1995). It does not consider the fact that in most production processes, natural and man-made capital (physical capital in particular) are complements. Strong sustainability implies that the use of non-renewable natural resources has to be ceased and that only the net annual growth rates of renewable natural resources may be used. 'Pure' weak or strong sustainability is therefore considered unrealistic. An appropriate interpretation of sustainability would lie somewhere in between the two extremes (Tisdell, 1997; Serageldin, 1996).

Effective tools for the operationalisation of sustainability development are sustainability indicators. From a macro-economic perspective, measuring sustainable development would be equivalent to measuring non-declining well-being over time, given an ideal composition of total capital. Indicators for this purpose have been proposed in the literature on environmental or 'green' national accounting (e.g., Atkinson et al., 1997; Aronsson, 1997; Perman et al., 1996).

Let us now turn to the discussion of agricultural sustainability indicators. According to the discussion in the previous section, a complete agricultural sustainability indicator would need to include the ecological and economic dimension, as well as the social dimension. However, Rigby and Cáceres (2001) point out that the construction of a single indicator combining information from all three dimensions is very difficult. Units and appropriate scales of measurement both differ within and across identified ecological, economic and social dimensions. Therefore, the construction of indicators always requires a trade-off between the extent to which the indicator captures necessary information and the ease of measuring and monitoring. Hansen (1996) suggests interpreting sustainable development in agriculture as a set of strategies that respond to the problems emphasised and that consider ideas of commonly accepted improvements. For example, a set of strategies may contain strategies for changing farming practices, such as the reduction of livestock density, which correspond to the problem of organic fertiliser surpluses. A commonly accepted aim is to reduce nitrate pollution generated by intensive agricultural livestock farming. A strategy of 'reduction of livestock density' may solve this commonly accepted problem. This example illustrates that specific strategies are more tangible and less vague than the term 'sustainability' and may facilitate the construction of proper indicators.

Agricultural sustainability indicators need to consider three basic aspects: 1) the magnitude of the agricultural sector, 2) the composition of agricultural output, and 3) the way in which output is produced. Responding to these three aspects demands an understanding of agricultural activities within the environment (Pearce, 1999). In this dissertation, we are mainly concerned with the third aspect, which refers to the intensity of agricultural land use.

The OECD (1999) has defined three major functions of environmental indicators in agriculture. Firstly, they should provide information to policy makers and the general public about the state of the environment as influenced by agriculture. Secondly, they should help policy makers better understand the cause-effect linkages between agricultural activity and the environment. Thirdly, they should assist in the evaluation of the effectiveness of agricultural and environmental policy instruments. In order to comply with these three demands, the OECD has proposed the Driving Force-State-Response (DSR) framework (OECD, 1999). Driving forces are the factors that cause environmental quality change. Agricultural land use intensity, natural processes and climatic conditions, but also economic and social factors, such as market signals, government policy and cultural aspects influencing agricultural land use, belong to the category of driving forces. The state-indicator describes the actual condition of the environment, e.g., the nutrient level in ground and surface water or the number of protected species in a certain area. Responses refer to the reactions of policy makers and groups in society to the state of the environment. A particular policy that may be a response would then again change the driving forces, which, in turn, influences the state of the environment. In fact, the state-phase in the DRS framework may be regarded as the most appropriate indicator for policy evaluation, since it gives direct information about the effects of a particular policy measure on environmental quality. However, especially in agriculture, it is also the most difficult one to assess. An important reason for this is the time and space dimension inherent in the cause-effect relationship between agricultural production and the state of the environment. The time and space dimension implies that the effects of agricultural pollution may become visible only after a number of years, or that the effects of agricultural production are spread over long distances through, for example, water or air. Another significant reason for this effect is that the assessment of state indicators is, in most cases, rather costly (Deblitz, 1999).

The indicators investigated in Applications A, B and C in the empirical part of this dissertation can broadly be categorised into three different types: environmental, behavioural and economic. Table 4.1 summarises the characteristics of the indicators in the three applications and indicates their position within the DSR framework.

Table 4.1 shows that Application A, the co-operative agreements between farmers and water suppliers, is concerned with an indicator of the environmental type. The variable under investigation in Application A is the nitrate level in groundwater, which indicates the state of the environment and which has evoked a response from water supply companies, namely the introduction of co-operative agreements as a particular policy form. This response involves a number of environmentally friendly farming practices that represent the ‘new’ driving forces, which may, in turn, influence the nitrate levels in groundwater.

Table 4.1: Description of indicators used in the three empirical cases

Indicator	***Application A***	***Application B***	***Application C***
Type	Environmental	Behavioural	Economic
Definition	• nitrate level in groundwater	• use of mineral nitrogen fertiliser • livestock density • grassland area per utilisable agricultural area	• land price elasticity with respect to agricultural income
Position in DSR framework	• state	• driving force	• state • driving force

The indicators in Application B, the agri-environmental policy programmes in the EU, are of the behavioural type. They are the result of a policy that has been implemented as a response to increasing environmental problems related to agriculture. Therefore, the indicators in Application B are the 'new' driving forces, which will, in turn, have certain effects on the state of the environment. The indicator in Application C, which investigates the capitalisation of agricultural income into land prices, is of the economic type. Its position in the DRS framework is ambiguous. From an economic viewpoint, it may be considered as a state. It does not, however, reveal anything about the state of the environment. From an environmental viewpoint, the indicator in Application C may be regarded as a driving force. Increased capitalisation of agricultural income (supported by agricultural policy measures) into land prices leads to the inflation of land prices, which may, in turn, induce intensive use of agricultural land and hence put increasing pressure on the environment.

4.3 Actors in the Policy-Making Process

Chapter 1 of this dissertation defines policy actors as stakeholders who are actively involved in the policy-making process, which implies that they have a direct influence on the outcome of the policy question under investigation. Actors in the political process of agricultural and environmental policy-making may be divided in two main groups. On the one hand, there is the government, acting through various agencies on different levels. On the other hand, there are specific sectors, such as the industrial, agricultural and service sectors, which are represented by trade unions, farmers' unions, employers' organisations and other lobbying groups (Verbruggen, 1994). The political composition of a government is, at least in a democracy, supposed to represent a society's preferences. Citizens do not usually vote directly for policies, except for occasional issues decided through referenda (Lindblom and Woodhouse, 1993).[12] Instead they trust government representatives in Parliament to act in line with their political preferences. Another way for citizens to influence policy-making is by organising themselves into special interest or pressure groups, such as environmental or consumer organisations. All actors play different roles in and have varying influences on the diverse stages of the policy-making process.

It was mentioned in the introduction that policy-making is a continuously ongoing process. In fact, the policy-making process can be regarded as a cycle. The literature proposes that the policy-making process is commonly structured in a cycle consisting of five different phases (Parsons, 1995; Dunn, 1994; Anderson, 1984). This cycle is depicted in Figure 4.1.

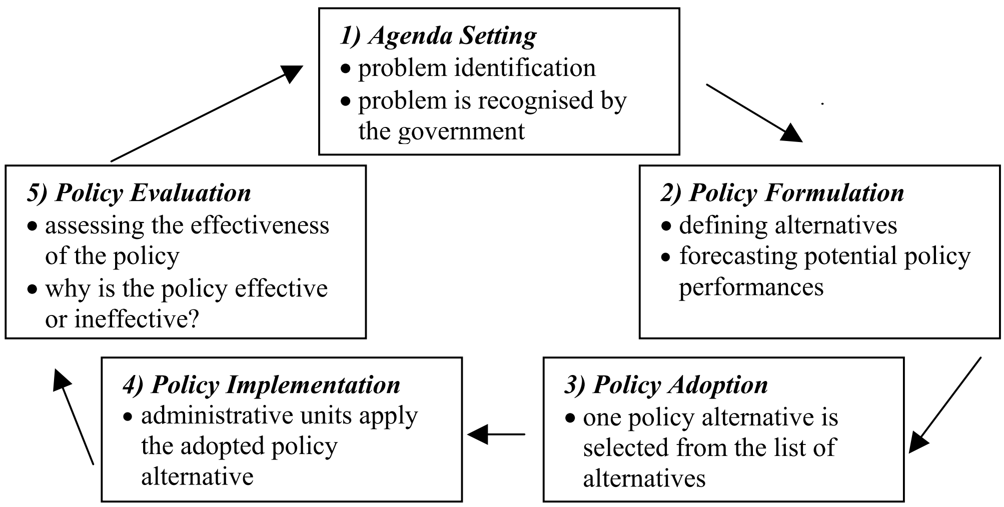

Figure 4.1: The five phases of the policy-making process

The policy-making process starts with the agenda-setting phase, in which a particular problem is identified and recognised by the government. Interest groups from different sectors in the economy and other social groups play an important role in this phase. They want to bring the problems and issues their groups are concerned about to the attention of government officials. An important aspect of agenda-setting is the identification of the problem's actual cause. Consider Application A, the problem of nitrate pollution in groundwater. Why do farmers apply nitrogen-containing fertiliser in excess of the assimilation capacity of the plants? Is the reason a lack of knowledge about the nitrogen content of the soil and the amounts of nitrogen plants are able to assimilate? Is nitrogen fertiliser cheap enough that farmers can afford to follow the rule 'the more the better'? Or, do farmers have to get rid of liquid

[12] Recently held referenda include the referendum on the adoption of the EURO in Denmark in 2000 and those on the enlargement of the European Union in Ireland in 2001 and 2002, respectively.

manure produced by their livestock? Certainly, the actual cause of the problem may be a combination of factors. Identifying and structuring the problem under consideration is a task for researchers and policy analysts.

The policy formulation phase includes gathering proposals for different policy alternatives. The actual policy proposals are developed by officials in the appropriate administrative departments and agencies. However, various interest groups have a significant influence in this phase. They inform government officials about different policy options and attempt to persuade them to choose options favouring their respective interest group (Anderson, 1984). The most important component of the policy formulation phase is the decision-making process, in which one of the alternatives from the list of competing alternatives is selected. The decision-making process is the link between the policy formulation phase and the adoption phase. The literature considers several theoretical frameworks for analysing decision-making. Economists make mainly use of the rational-comprehensive framework, in which individuals are regarded as calculating self-interested individuals. Other decision-making frameworks include power approaches, public choice theory, institutional approaches and informational and psychological approaches (Parsons, 1995). Another important issue to be considered in the policy formulation stage is the choice of the policy instrument with which a certain policy goal is supposed to be reached (Howlett, 1991). Policy instruments will further be elaborated upon in Section 4.5.

Policy implementation is mainly an administrative process carried out by a complex system of governmental agencies that mobilise financial and human resources to comply with the policy (Dunn, 1994). It is important to note that the content of an adopted policy option may be modified, elaborated or even negated during the implementation phase. Actors that may influence the implementation phase are the legislature, the court, interest and pressure groups and other organisations (Anderson, 1984).

The evaluation of a policy should consider two dimensions. First, a policy may be measured against the goal the policy is meant to attain. In other words, the effectiveness of a policy is assessed. Second, the actual impact of a policy may be measured (Parsons, 1995). The second point includes all the side effects of a certain policy that are not considered in its formulation phase. A necessary requirement for policy evaluation is monitoring, which helps to assess degrees of compliance, discover unintended consequences and identify implementational obstacles and constraints. Tools for monitoring include indicators constructed for the various policy fields (Dunn, 1994), such as those developed for sustainable agricultural land use described above. Depending on the evaluation results, i.e., the policy outcome, a policy may be maintained, revised or abandoned. It may also show a demand for new policies, which will initiate a new policy cycle.

The five phases of the policy-making process may be carried out on different governmental levels. For example, agenda-setting and policy formulation for a particular problem may occur on the national level, whereas the actual implementation of the policy may be carried out on lower governmental levels. The issue of the optimal level of government is elaborated upon in the following section.

4.4 Levels of Government

The theory of fiscal federalism and multilevel government systems says that the different governmental levels should be responsible for different tasks. In general, central governments, such as national governments or the EU government, should be concerned with macro-economic stabilisation and income redistribution. On the other hand, lower level governments should be responsible for the allocation of resources since they are better informed about the local society's preferences. The latter statement is particularly true for the case of local public goods. The benefits of local public goods are restricted to certain areas, implying that only the people who live in (or visit) these areas can make use of the public goods (Stiglitz, 1986). Agricultural land has many characteristics of a local public good, such as the recreational function or the function of supporting open space, local wildlife habitats and ecosystems. Accordingly, negative externalities from intensive agricultural land use often have the characteristics of local public 'bads'.

Verbruggen (1994), citing Tinbergen, points out that the optimal government level to be responsible for a particular problem is the level beyond which no externalities occur. This idea is also captured in the subsidiarity principle, which the European Commission established in the Single European Act in 1986. The subsidiarity principle assigns decision-making and the enforcement of environmental policies to the lowest level of government capable of handling them without significant residual externalities (Turner and Opschoor, 1994). The optimal government level to deal with a particular environmental issue therefore depends on the spatial scale of the respective environmental good or bad. Verbruggen and Jansen (1995) distinguish between four different dimensions that characterise the spatial scale of an environmental externality, which should determine the optimal government level for policy negotiations.

1) the geographical extent of an environmental good or system (e.g., river, lake, forest or wetland),
2) the pattern of transport of pollutants (air, water, soil; short or long distance),
3) the pattern of trade flows in cases where traded products are media of environmental effects,
4) psychological spillover effects when the degradation of ecosystems or treatment of animals in one country affects the psychological well-being of other people in other countries.

We employ Application A to illustrate the first and the second dimension. Nitrate pollution of groundwater is of a relatively limited geographical extent. In many cases, the groundwater pollution is restricted to certain wells in the water catchment area of a particular water supply company. Furthermore, in the case of groundwater, the transport of the polluting substances mainly shows a vertical pattern. In other words, the point of nitrogen emission lies in most cases directly above the point at which pollution occurs, i.e., in the groundwater resources that are situated under intensively used agricultural land. Additionally, the polluting substances in a particular groundwater aquifer do not usually disperse over great distances but stay close to the area where the pollution occurs. Polluters and victims are therefore located in the same area, which implies that policies aiming at limiting nitrate pollution of groundwater resources should be implemented at relatively low levels, such as local or other sub-national levels. The co-operative agreements between farmers and water suppliers are an example of policy implementation at the water catchment level. The water supply company and its customers, who are usually located in the vicinity of the water supply company, are the stakeholders that benefit most from a reduction in nitrate pollution that has been caused by farmers located in the catchment area of the water supply company. An example representing the need for policy intervention on global level, is the emission of greenhouse gases, which are uniformly mixing global pollutants dispersed through the air. Through the Kyoto Protocol, this type of pollution is addressed on a supra-national level.

4.5 Policy Instruments

Agricultural and environmental policy instruments can generally be divided into three main categories: 1) direct regulation or command-and-control instruments, 2) economic or market-based instruments and 3) communicative or persuasive instruments (Verbruggen, 1994). Table 4.2 shows some examples of the three types of policy instruments affecting agricultural land use.

Table 4.2: Examples of three types of policy instruments

Direct regulation	Economic instruments	Communicative instruments
• public land use planning (zoning/spatial planning) • pollution standards • prohibition of particular agro-chemicals and agricultural production methods	• taxes • subsidies • price support • import/export tariffs • tradable rights and quotas	• agricultural extension service • public education and persuasion • co-operative approaches

The most basic policy regulating agricultural land use is public land use planning, which falls under direct regulations. Public land use planning, such as zoning or spatial planning, which is especially important in European countries, determines where agricultural production may take place. Within the framework of this dissertation, we mainly want to focus on policies that are meant to control externalities. Subsection 4.5.1 focuses on economic instruments, particularly taxes and subsidies. Subsection 4.5.2 deals with communicative instruments, especially focussing on co-operative approaches based on the *Coase Theorem*.

4.5.1 Taxes and subsidies

Subsection 3.3.3 in the previous chapter presented a theoretical concept showing that Pigouvian or corrective taxes and subsidies may be applied in order to correct for negative and positive externalities from agricultural land use. It has been pointed out that under the condition that marginal costs and benefits for a particular type of land use are known, this type of taxes and subsidies may indeed lead to a Pareto-efficient allocation of resources and hence to an improvement in economic efficiency. In such a situation, the imposed tax or subsidy may be regarded as optimal, which is often referred to as the first-best correction of an externality problem (Zilberman and Marra, 1993).

However, although progress has been made in the estimation of non-market values, the precise determination of environmental costs and benefits is still problematic, so that the imposition of taxes and subsidies to correct for the externality problem does not necessarily result in a first-best solution. Another issue concerning the information requirement deals with the fact that the cost and/or benefit functions of all firms need to be identical if an overall uniform tax and/or subsidy would be applied. Especially in the agricultural sector, where there are many firms with different production and management structures, uniform cost and/or benefit functions are very unlikely. Zilberman and Marra (1993), referring to Baumol and Oates, mention that a second-best solution has to be applied if a first-best solution is not feasible. Their second-best solution implies that the policy maker determines some aggregated environmental target and that the least-cost policy may be implemented to reach the target. The second-best solution may be a tax or a subsidy; it does not, however, result in a Pareto-optimal allocation of resources.

In a discussion of subsidies as a policy instrument for resolving the externality problem, a number of important aspects must be mentioned. A subsidy to reward the production of positive externalities may, under the mentioned condition, indeed result in a Pareto-optimal resource allocation. However, a considerable number of subsidies are granted to pollution abatement, which implies the reduction of negative externalities. Stiglitz (1986) emphasises that subsidising pollution abatement does not result in socially-efficient resource allocation. The total marginal social costs of private production include, along with the external costs arising from the pollution from private production, the costs of government subsidies for abatement. Polluting firms do not take these additional social costs into account. The social marginal cost curve thus continues to exceed the private marginal cost curve, which implies that the level of production is still too high. Furthermore, Baumol and Oates (1975) mention that the uncontrolled granting of subsidies may attract new firms into a business or may keep inefficient firms in the business, which may off-set the pollution reduction attained by a single firm. Granting subsidies for pollution control may not be regarded as unfavourable in general. It must be noted, however, that the previously discussed issues concerned with the use of subsidies for pollution abatement need to be taken into account in the policy-making process.

4.5.2 Communicative instruments

In our discussion of communicative instruments, we want to focus on co-operative approaches based on the Coase Theorem. The discussion is illustrated with an example from Application A, the co-operative agreements between water supply companies and farmers. Coase (1960) proposed that direct bargaining between polluters and victims is superior to government intervention via taxes, subsidies or direct regulation in order to reach the social optimum. An indispensable requirement for direct bargaining is the adequate assignment of property rights. It is important that property rights *be* assigned. The *allocation* of property rights, indicating who holds the property rights, is not important for reaching a socially optimal situation. The allocation of property rights 'only' has implications for the distribution of costs and benefits because it determines the direction of the stream of compensation payments. The mechanism of the Coase Theorem is visualised in Figure 4.2.

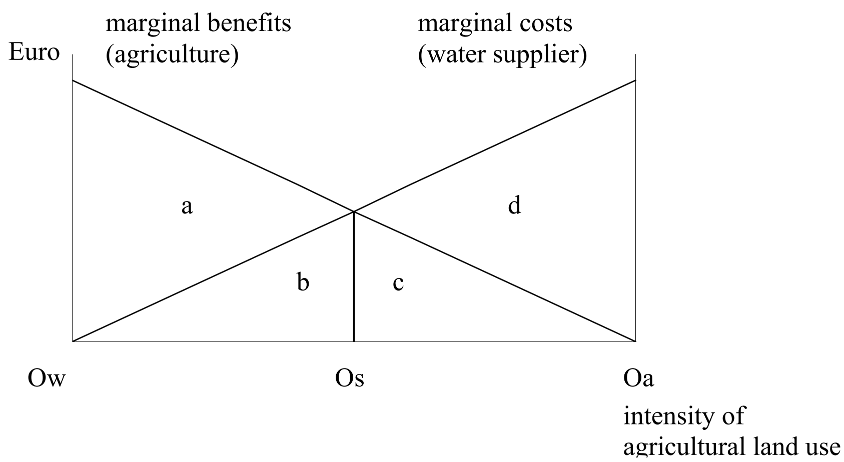

Figure 4.2: Direct negotiations between water supply companies and farmers

Figure 4.2 shows the marginal cost and benefit curves for the water supply company and the farmers, respectively.[13] The horizontal axis indicates the intensity of agricultural land use. Intensifying agricultural land use implies production expansion

[13] If multiple farmers are involved, it must be assumed that all farmers have identical marginal benefit curves.

along the intensive margin (see Section 2.3 in Chapter 2) and may be associated with increasing levels of agricultural pollution in groundwater. In a world without competition for the intensity level of agricultural land use, the farmers would produce at an intensity level O_a, at which the marginal benefits of intensifying agricultural land use are equal to zero. Accordingly, the water supply company would choose an intensity level at point O_w, where marginal cost equals zero.[14]

In the case of the co-operative agreements between water supply companies and farmers, farmers are compensated for complying with certain restrictions leading to a reduction of the intensity level of agricultural land use. Theoretically, according to Figure 4.2, the water supply company would compensate the farmers up to the area (c+d), i.e., up to the point at which the marginal costs of pollution cease to exceed the marginal benefits of pollution, in order to reach the equilibrium level of pollution, O_s. The fact that the water supply company compensates the farmers implies that property rights are assigned to the farmers, as has already been pointed out in Subsection 3.4.2 in Chapter 3. However, even if the property rights were allocated to the water supply company, the equilibrium intensity level of agricultural land use would be reached. In such a case, the farmers would be willing to pay the water supply company up to the area (a+b) for permission to increase the intensity level of agricultural land use. Corresponding to the previous case, the same equilibrium level would be reached, since the farmers would only pay up to the point at which marginal benefits cease to exceed the marginal cost.

There are, however, a number of concerns attached to the Coase Theorem. Baumol and Oates (1975) point out that voluntary agreements are only applicable in small number cases, which means in situations where only a limited number of parties is involved. The main complications that arise in direct bargaining between polluters and victims when the number of participants becomes critically large are transaction costs, i.e., the administrative and coordination costs involved in getting individuals together. It is hence not surprising that the co-operative agreements described in Application A occur at the local level, namely, in the water catchment area of a particular water supply company. This does, however, not imply that co-operative approaches may not be feasible when the number of participants is large. Zilberman and Marra (1993) point out that direct bargaining between polluters and victims is likely to be more efficient than government intervention, since direct bargaining tends to ensure that all incentives for changing the outcome are exhausted. They also suggest that, even in cases with high transaction costs, government intervention may be inferior to direct bargaining. In some cases, it may be more advantageous to spend government resources on lowering transaction costs rather than on other types of regulation and enforcement.

[14] An intensity level at point O_w may describe a situation in which there is no agricultural production.

4.6 Conclusions

Policy-making is a continuously ongoing process and new policy issues may be generated through the implementation of previously-defined policy options. The objectives of policies regarding particular sectors or particular groups in an economy normally change over time, reflecting changing social preferences. The current policy objective in almost all fields of policy is sustainable development. Sustainable development is a very broad term and it remains difficult to choose between actual policy options for attaining sustainable development. The most fundamental difficulty with this objective is the fact that whether or not a particular policy option has turned out to be sustainable may only be determined *posteriori*.

Sustainable development needs to take place along three dimensions, namely, the ecological, economic and social dimensions. The current discussion on sustainable development is very often biased towards the ecological dimension. With regard to the environmental issues, it is often stated that the supportive agricultural policies introduced in the first half of the twentieth century are unsustainable since they lead to the exhaustion and pollution of soil and water resources. It is, however, very unlikely that agricultural policy-makers after the Second World War would have taken the ecological dimension into account, which would imply that they deliberately risked the ecological value of agriculturally-related environmental resources. Would it not be much more likely that former agricultural policy-makers considered the economic and social dimensions of the agricultural sector unsustainable? The post-war period was marked by food shortages and public preferences presumably were for sufficient food supply rather than for the ecological value of environmental resources, in order to *sustain* human nutritional requirements. Returning to the current situation, it is certainly true that extensive agricultural production methods relieve the pressure on the environment and may follow the track of ecological sustainable development. It is, however, questionable whether they are also able to meet the nutritional needs of a growing world population, which would imply unsustainable development along the social dimension.

It becomes obvious that a certain policy that is regarded as the correct option at a certain point in time may not be appropriate at another point in time. Regarding the agricultural sector in western, industrialised countries, we are currently at a point in time at which the ecological dimension of sustainable development receives the most attention. Ecologically sustainable development may be measured with the help of indicators that aim at measuring the effects of particular agricultural practices on the environment. Tangible indicators are needed in order to use the ‘fuzzy’ concept of sustainable development for practical policy-making. The policy-making process may result in the application of different types of policy instruments, such as taxes, subsidies or co-operative approaches, which are supposed to encourage more efficient use of environmental resources and which are ultimately meant to encourage sustainable agricultural development.

CHAPTER 5

RESEARCH SYNTHESIS, COMPARATIVE ANALYSIS AND META-ANALYSIS

5.1 Introduction

The complexity of current policy issues in agriculture due to the inherited burdens from former policies, an increase in stakeholder diversity and changing preferences in society has created a tremendous increase in the demand for research to provide advice to public policy-makers. Along with increased demand for policy research, the supply of policy-related studies has risen steadily over the past decades. This is especially true for quantitative studies, due in large part to personal computers' increasing capability to store and process large amounts of data. Simultaneously, recent developments in the ICT sector have facilitated information-gathering, which has led to a considerable increase in the accessibility of research about policy evaluation and analysis. Increased demand for policy research and increased availability of information from previously performed research seem to provide comfortable conditions for researchers. However, the availability of large numbers of studies on certain policy questions has disadvantages as well. The larger the number of existing studies, the wider the variety of study outcomes, and the wider the variety of geographical and temporal settings or research methods applied. This richness of information may constitute a problem because of the human mind's finite capacity to store and systematically recall large amounts of information. The increasing availability of previously performed research on a particular policy issue may only be considered beneficial if we have appropriate techniques at our disposal to use in structuring and organising the available information (Button, 1998).

Another question arising from the availability of large amounts of information, not only as reported in scientific articles and well-documented case studies but also in fragmented and scattered forms as included in various research reports for policy advice, is whether existing research has always been evaluated and exploited properly before new research is begun. Scientific knowledge-building cannot only be attained by performing new primary research but also by reassessing findings from existing research.

Research synthesis, and in particular, comparative research and meta-analysis may offer solutions for these two problems. In order to get a better idea of the actual meaning of the three terms, Section 5.2 proposes a categorisation that attempts to identify the differences and similarities between them. Subsequently, Section 5.3 provides an overview of a number of different techniques for research synthesis. In particular, the section focuses on conventional statistical methods for meta-analysis, meta-regression analysis and classification techniques for comparative research. Section 5.4 describes some problems that are specifically inherent to meta-analysis. This chapter closes with some concluding remarks in Section 5.5.

5.2 Differences and Similarities

5.2.1 Research synthesis

Research synthesis or research integration, as it is defined by Cooper and Hedges (1994a), "*… involves the attempt to discover the consistencies and account for the variability in similar-appearing studies*". It is concerned with summarising empirical research findings by drawing overall conclusions from several separate investigations addressing identical or related research questions. Furthermore, research synthesis aims at presenting the state of knowledge about the problem of interest and at pinpointing important issues that previous research has left unresolved (Cooper, 1998). In short, it summarises, compares and integrates the results of primary and secondary analyses.[15]

Glass (1976) distinguishes meta-analysis as a follow-up to primary and secondary analysis. Here, we state that meta-analysis is only one way to perform research synthesis. We want to distinguish between primary analysis, secondary analysis and research synthesis. This view is also held by Cooper (1998) who divides research synthesis into two major branches. One branch consists of narrative literature reviews that appear as detailed work independent of new primary analyses.[16] The other branch is the quantitative form of reviewing literature, i.e., meta-analysis as defined in greater detail later. To the two branches, narrative literature review and meta-analysis, we want to add a third method of performing research synthesis, that is, comparative analysis of case studies. Figure 5.1 summarises the relationship between the various terms that have appeared in the preceding discussion.

Figure 5.1, as well as the title of this chapter, indicates that in the context of this dissertation, we will mainly concentrate on comparative analysis and meta-analysis as ways of performing research synthesis. As opposed to narrative literature reviews, comparative analysis and meta-analysis are quantitative forms of research synthesis.

[15] Primary analyses are analyses of 'new' data to answer a particular research question. Secondary analyses are re-analyses of the data to answer the same research question with new analytical techniques or to answer new research questions with old data (Glass, 1976).

[16] Cooper (1998) calls a literature review that appears as a brief introduction to new primary studies, a theoretical literature review. This type of literature review is quite narrow and is mainly restricted to major theoretical and empirical work, usually focusing on the issues addressed in the new primary study.

Independent narrative literature reviews aim at, for example, integrating and criticising the work of others, connecting related research areas, identifying central issues in a particular field and deriving some general conclusions from existing studies (Cooper, 1998). They are widely used and their use has long been established in economic science, which manifests itself in the existence of two economic journals explicitly aimed at literature reviews, i.e., the Journal of Economic Literature and the Journal of Economic Surveys (Button, 1998).

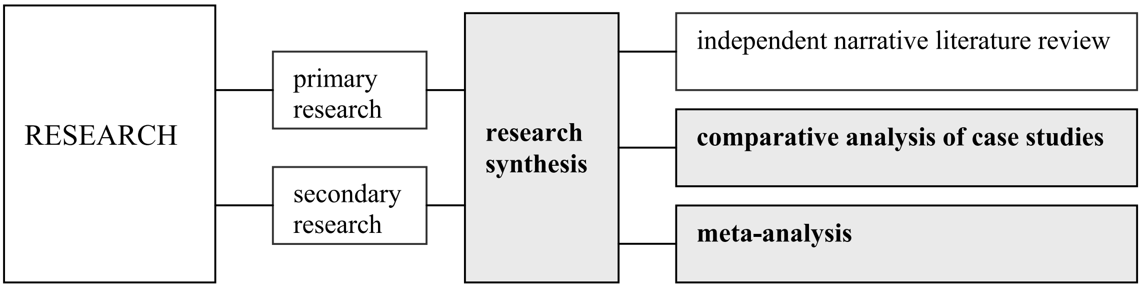

Figure 5.1: Relation between research synthesis, comparative analysis and meta-analysis

However, qualitative forms of research synthesis, such as independent narrative literature reviews, have a number of disadvantages compared to quantitative forms of research synthesis. The most prominent advantage of quantitative research syntheses is a reduction of the level of subjectivity (Florax et al., 2002a; Van den Bergh and Button, 1999). The selection of studies to be included in a qualitative literature review is often the result of the reviewer's own impression of the quality of the studies, which is often based on particular methodological or theoretical considerations (Wolf, 1986). It is certainly true that empirical studies may involve theoretical or methodological issues. It is, however, questionable whether a purely qualitative judgement of the potential theoretical or methodological problems included in a particular study is justifiable. Quantitative forms of research synthesis are able to actually pinpoint and, if possible, estimate the impact of theoretical or methodological issues across the full range of studies (Stanley, 2001). Furthermore, if a majority of studies show similar conclusions, these are more likely to be accepted as the true results, regardless of the quality of the data used or the analytical technique employed (Button et al., 1999). Study findings that contradict the beliefs of the majority are often disqualified. It should be noted that quantitative forms of research synthesis cannot fully avoid the subjectivity problem, but, at least, can make certain judgements more transparent (Van den Bergh and Button, 1999). Another advantage of quantitative research synthesis over qualitative forms of research synthesis is their more systematic approach to analysing the varying results of previous research (Florax et al., 2002a). A purely qualitative examination of existing study results on the same research question often fails to include specific study characteristics as potential explanations for consistencies or discrepancies across study results (Wolf, 1986).

It has been mentioned above that, within the framework of this dissertation, we are concerned with the comparative analysis of case studies and with meta-analysis as ways to perform research synthesis. The following two subsections give a more detailed description of the comparative analysis of case studies (Subsection 5.2.2) and meta-analysis (Subsection 5.2.3). Subsection 5.2.4 identifies the type of research synthesis applied in Applications A, B and C in the empirical part of this dissertation.

5.2.2 Comparative analysis of case studies

Comparative Analysis in general has a very broad meaning. It basically aims at identifying the common and contrasting elements that characterise a certain phenomenon under investigation (Nijkamp et al., 1999). The phenomenon under investigation may be described in several different ways, such as single descriptive or quantitative case studies, individual data from official sources, scattered and fragmented information in various research reports, responses to questionnaires and articles published in scientific journals. Furthermore, comparative analysis may be carried out with the help of various different tools, including descriptive and qualitative analysis, classification techniques, statistical techniques and other quantitative methods. The range of comparative analyses is indeed quite wide. Pickvance (2001) stresses quite rightly that strictly speaking all analysis is comparative. To illustrate this, a standard time-series analysis based on, for example, official data series *compares* observations of the same phenomenon over time and a standard cross-section analysis *compares* a particular phenomenon over space. In fact, a particular 'number' gets its meaning only when it is *compared* to another 'number', i.e., a benchmark, a reference point or some other type of starting point. In other words, an analysis only makes sense if it is based on a comparison between at least two settings.

The preceding discussion shows the difficulty of pointing out the actual differences between comparative analysis and analysis in general. Consequently, it is rather cumbersome to find a general definition of comparative analysis. However, in the context of this dissertation, we want to reserve the term 'comparative analysis' specifically for the comparison of previously performed case studies and other ways of describing particular situations. An important criterion for the different case studies or 'situations' to be compared is that they must be meaningful when regarded individually. Consider, for example, Application A, the co-operative agreements between water suppliers and farmers. The individual observations in the analysis are the responses of water supply companies to a questionnaire about the set-up and functioning of the co-operative agreements in their working area. Each questionnaire contains information about the performance of the co-operative agreement a particular water supply company offers to farmers. For the particular water supply company, the information given in the questionnaire is sufficient for evaluating the performance of the co-operative agreement. The water supply company does not need any other information, such as performance indicators for the co-operative agreements offered by other water supply companies, as a benchmark in order to interpret the results of their own co-operative agreement. In short, the information included in one questionnaire is already meaningful when regarded individually.

Another characteristic of comparative analysis of case studies as it is defined within the framework of this dissertation refers to the type of data being analysed. This characteristic is of particular importance for differentiating comparative analysis of case studies from meta-analysis. The type of data to be investigated in a comparative analysis of case studies needs to be ‘raw’, ‘individual’ or primary, which implies that they may not be statistically summarised or aggregated from a larger, underlying data set. The application of aggregated data characterises meta-analysis, which is further defined in the following subsection.

5.2.3 Meta-Analysis

Meta-analysis, as defined by Glass (1976), refers to “*the statistical analysis of a large collection of analysis results from individual studies for the purpose of integrating research findings*”. This definition suggests that meta-analysis especially focuses on the comparison of the outcomes of previously-performed primary studies by means of quantitative and, in particular, statistical techniques (Cooper, 1998; Cooper and Hedges, 1994a; Rosenthal, 1991). Other definitions describe meta-analysis as a statistical approach to reviewing and summarising the literature and also as a quantitative literature review (Stanley, 2001). The actual difference between meta-analysis and comparative analysis is that meta-analysis makes use of aggregated data or statistical summary findings from empirical studies. Comparative analysis as described above does not necessarily make use of aggregated data. It may also apply raw or individual data.

Section 2.5 in Chapter 2 has already pointed out that medical research, psychology and the natural sciences are the traditional fields in which meta-analytical research has been employed. The development of statistical research synthesis in these scientific fields is a consequence of the availability of numerous primary repetitive studies on the same research question, carried out in a (quasi-) experimental and largely standardised context. These conditions provide an appropriate basis for statistical meta-analyses. Research and research reports in the medical sciences have a rather uniform structure (Van den Bergh et al., 1997). In economic science, this protocolistic way of researching and reporting is lacking. There are no general guidelines on *how* to report the actual research performance and the results of an empirical study nor on the minimum amount of information about the statistical properties of the estimated results. For example, we still encounter studies published in economic journals that lack information on standard deviations, *t*- or *p*-values or sample sizes.

Furthermore, in contrast to those in economic science, repetitive studies in medical research and psychology are rather common and even advisable. Certainty about questions concerning the life and death of human beings is obviously more important than certainty about, e.g., a particular elasticity of demand. Studies in economic science are appreciated and are considered worth of publication if they present, for instance, a new methodological or econometric approach that distinguishes them from other, previously published studies. Updated results generated by the replication of earlier performed studies may be interesting for policy makers. In most cases, however, these are not important enough to be published in an economic journal (Smith and Pattanayak, 2002). Smith and Pattanayak (2002) point out that the publishing policy in the field of economics stands in sharp contrast to those in other fields of applied science, where estimated effects are the most interesting results and new, replicative estimates are published since there is interest in the estimated effects themselves.

Primary studies in the traditional field of meta-analysis mainly consist of a comparison between two groups, a control and an experimental group, with the aim of examining whether a certain treatment has a significant effect on a particular phenomenon under investigation, for example, whether a particular medication has an effect on the risk of heart attacks. The advantage of these experiments is that most of them are carried out in a similar set-up or, alternatively, that differences in the set-up can easily be controlled for (Florax et al., 2002a). Notably in the medical science, meta-analysis has been approved as a valuable tool for making the most efficient use of experimental data from clinical trials of new drugs and medical treatments. Clinical trials are very expensive undertakings and often result in contradictory and unreliable outcomes. By combining contradictory results from individual clinical trials, meta-analyses may often come to clear conclusions (Stanley, 2001, citing Zivin, Antman et al. and Hunt).

The lack of experimental and standardised conditions in many of the social sciences, including economics, is an obstacle for applying meta-analysis in a non-experimental context. In order to be able to compare existing research results in a strictly statistical way, they should be concerned with quantitative factors measured in identical units, or they should, at least, be transformable into some common unit or index (Van den Bergh et al., 1997). A unit that is widely used in economic science and that has appropriate characteristics for meta-analytical research is elasticity. It is hence not surprising that a considerable number of meta-analyses in economics investigate differences and similarities between empirically estimated elasticities. The following table gives a selection of economic studies presenting meta-analyses on particular types of elasticities.

Table 5.1: Examples of meta-analyses in economics using elasticities

Study	*Type of elasticity investigated*
Kremers et al., 2002	Price elasticity of transport demand
Dalhuisen et al., 2003	Price and income elasticity of residential water demand
De Mooij and Ederveen, 2001	Tax elasticity of foreign direct investment
Hakfoort 2001	Output elasticity of public capital
Nijkamp and Poot, 2002	Wage curve elasticity (unemployment)
Espey and Thilmany, 2000	Wage elasticity of farm labour demand
Nijkamp and Pepping, 1998	Price elasticity of transport demand
Espey et al., 1997	Price elasticity of residential water demand
Espey, 1996, Espey, 1998	Price elasticity of gasoline demand
Nijkamp and Pepping, 1997	Price elasticity of pesticide demand
Phillips and Goss, 1995	Tax rate elasticity of economic development
Smith and Kaoru, 1990a,b	Price elasticity of recreation demand

Although the unitless character of elasticities facilitates their comparability in a meta-analytical framework, there are still potential sources of heterogeneity among elasticities that, at first sight, may appear similar. The heterogeneity may be due to, for example, the exact specification of the elasticities in the underlying empirical studies or the precise definition of the data series on the basis of which the elasticities in the underlying studies are estimated. For example, De Mooij and Ederveen (2001) encounter three different definitions of tax elasticities in the underlying studies in their meta-analysis on the effects of taxation on foreign direct investment. In such a case, the meta-analysts have to find an appropriate method of transforming the elasticities into a common specification. In most cases, the elasticity transformation requires some additional information, such as information on the mean values of the dependent and/or independent variable. Ideally, this information is included in the respective underlying empirical studies. If this is not the case, external data sources may have to be consulted in order to retrieve the required information. Application C in the empirical part of this dissertation provides another example of a meta-analysis on elasticities, i.e., the elasticities of land prices with respect to agricultural income. The comparability problem in the meta-analysis of Application C is mainly caused by differences in the definitions of the agricultural income data series. Chapter 8 suggests a method that may mitigate the comparability problem in Application C.

Apart from meta-analyses that are concerned with elasticity measures, a considerable number of meta-analyses have been performed in the field of monetary valuation of environmental goods. Monetary valuation measures (e.g., consumer surplus or willingness-to-pay), even if they stem from different countries and different time periods, are easily transformable into comparable estimates by applying, for example, GDP deflators and Purchasing Power Parities. They are therefore another appropriate input variable for a meta-analysis. Specific environmental economic topics investigated in a meta-analytical framework range from urban air pollution (Smith and Huang, 1995; Smith and Huang, 1993; Schwartz, 1994) and outdoor recreation (Shrestha and Loomis, 2001; Rosenberger and Loomis, 2000; Bateman and

Lovett, 1999; Smith and Osborne, 1996; Carson et al., 1996; Walsh et al., 1992; Smith and Kaoru, 1990a,b) to other environmental issues, such as endangered species (Loomis and White, 1996, water quality (Bergstrom et al., 2001) and wetland services (Woodward and Wui, 2001; Brouwer et al., 1999).[17] There are three major factors that have caused the increase in meta-analytical research in the field of environmental valuation. First, the growing policy relevance of incorporating environmental values into cost-benefit frameworks has lead to a tremendous increase in the availability of environmental valuation studies. Second, the estimated monetary values resulting from the valuation studies differ widely. Third, meta-analyses can be used for environmental value and benefit transfer, i.e., the application of monetary environmental values estimated at one site for other sites. Carrying out an environmental valuation study is rather costly, both financially and in terms of manpower involved. Meta-analyses are regarded as an attractive alternative to original research for informing policy-makers about environmental values at a particular policy site (Brouwer, 2000; Van den Bergh and Button, 1999).

Initially, the main aim of meta-analyses in the traditional fields was to aggregate the results of individual studies into a grand average and to identify whether a particular treatment had a significant effect. Although this objective is still maintained, contemporary meta-analyses in these fields put more emphasis on explaining variances among the results of the individual studies than on averaging them (Lipsey and Wilson, 2001). Some meta-analyses in economic science also have the aim of averaging the results of previous studies and identifying whether particular effects were present. However, most of the economic meta-analyses are concerned with the variations in previous study results. The following list identifies nine different objectives of meta-analyses in economic science (Van den Bergh and Button, 1999; Van den Bergh et al. 1997).

1) Summarising a collection of similar studies, relationships or indicators
2) Averaging, possibly using weights, for collecting values obtained in similar studies
3) Comparing, evaluating and ranking studies on the basis of well-defined criteria or goal functions
4) Aggregating studies, by taking complementary results or perspectives
5) Identifying common elements in different studies
6) Comparing outcomes and different methods applied to similar questions
7) Tracing factors that are responsible for differing results across similar studies
8) Environmental value and benefit transfer
9) Finding directions for new primary research

[17] For an interesting overview of meta-analyses in environmental valuation see Smith and Pattanayak (2002).

The different objectives may require different types of techniques. Methods for research synthesis will be further described in Section 5.3. With regard to point 9), finding directions for further research, the role of meta-analysis in Bayesian approaches needs to be mentioned. The Bayesian approach is a method to update a prior probability distribution of a particular effect size with new primary data in order to produce a posterior probability distribution. Subsequently, the posterior distribution can act as an updated prior distribution for the next investigation with new primary data. A meta-analysis can assist in developing an objective prior distribution for a Bayesian analysis (Louis and Zetterman, 1994). The Bayesian approach can incorporate evidences from the studies in the meta-analysis, such as influences of study characteristics, within the prior probability distribution. The resulting posterior distribution gives then an honest level of uncertainty that includes the relevant factors of variability. A further elaboration on the Bayesian approach to meta-analysis is not provided in this dissertation. It would, however, certainly be interesting to investigate this issue in more detail in the future.

5.2.4 Types of research synthesis used in Applications A, B and C

Having defined the differences and similarities between research synthesis, comparative analysis of case studies and meta-analysis, we can identify the types of analyses used in the empirical applications in Part II of this dissertation. Subsection 5.2.2 has identified Application A, the co-operative agreements between farmers and water suppliers, as a comparative analysis of case studies. The individual questionnaires contain 'raw' information about the performance of the co-operative agreements. The water supply companies do not report any aggregated or statistically summarised data that result from estimations on the basis of larger, primary data sets. Application A is thus not a meta-analysis, but a comparative analysis of case studies.

Application B, agri-environmental policy programmes in the EU, is based on case studies that investigate the environmental effectiveness of agri-environmental policy programmes. The case studies are carried out within the same research project. Although the case studies have not been performed independently of each other but within the framework of a specific research project, they are also meaningful when regarded separately. The case studies are all based on a uniform research set-up including identical questionnaires applied in different regions in Europe. With respect to the underlying research methodology, there is no variation among the case studies. However, the type of data given in the case studies are aggregated, statistically summarised data. The original information, namely, the responses to the individual questionnaires are not available for analysis. Application B may therefore be regarded as a meta-analysis.

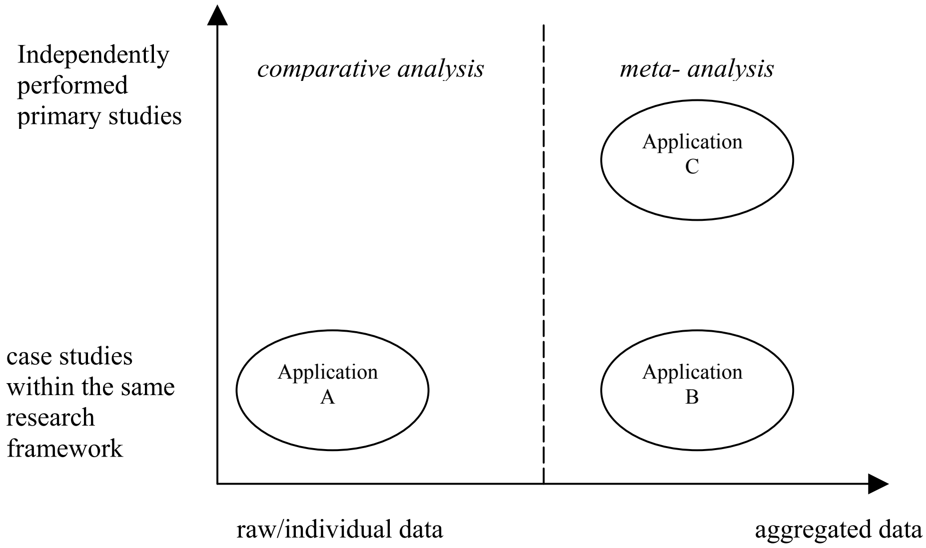

Figure 5.2: Types of research synthesis in Application A, B and C

Application C, the effects of agricultural income on land prices, can be strictly defined as a meta-analysis. Here, the research outcomes, the estimated elasticities of independently performed studies, are compared in a statistical way. Figure 5.2 shows the differences between the types of research synthesis employed in Applications A, B and C.

The three applications also differ with respect to the analytical method used to synthesise the information. A concise description of the analytical methods used in the three applications and of other techniques for research synthesis is given in the following section.

5.3 Techniques for Research Synthesis

5.3.1 Different types of information

The previous sections pointed out that one of the major differences between comparative analysis in general and meta-analysis in particular is the form of data serving as input for the two forms of analysis. Meta-analysis makes use of aggregated data, i.e., statistically estimated magnitudes, such as elasticities or willingness-to-pay, since the original, primary data on which the statistically estimated magnitudes are based are not available. The difference between general analytical techniques and meta-analytical techniques boils down to the fact that the observations to be investigated, or, in other words, the data that serve as dependent and independent variables, can be regarded as summary information that stem from various studies with differing properties and characteristics. This fact creates a number of methodological issues inherent to meta-analytical research that are less obvious in primary empirical research. These issues may require special attention, which may not be required for primary empirical research since it makes use of uniform data sets. However, the actual techniques for meta-analytical research are no different from techniques for empirical research in general. For example, a meta-regression analysis is based on the same statistical approach as a conventional regression analysis. We will come back to the methodological issues inherent in meta-analysis in Section 5.4.

An important concept in meta-analytical research, which, according to the preceding discussion, is concerned with the type of data used as input for the analysis, is the effect size. In general, the effect size represents the size of a relationship between two variables, such as the size of the effect of an independent variable on a dependent variable (Rosenthal, 1991). Obviously, effect sizes are the statistical estimates that result from primary empirical research. Effect sizes are the dependent variable, i.e., the variable to be explained, in a meta-analysis. A frequently estimated effect size in economics is elasticity. The traditional fields of meta-analysis, medical research and psychology, employ other types of effect sizes. To be precise, the effect sizes used in these fields can basically be divided into two families. The first family, called the *r* family, includes different types of Pearson's correlation coefficients. The second family, called the *d* family, includes different forms of standardised mean differences, which basically compare the means of a particular variable from two groups (an experimental and a control group) standardised by the population standard deviation. This type of effect sizes indicates whether an experimental group that is exposed to some kind of treatment has a significantly different mean value of the investigated variable than the mean value of a control group. In other words, the effect sizes indicate in a standardised manner whether a certain treatment has an effect. Prominent effect sizes of the *d* family are Hedges's *g*, Glass's Δ or Cohen's *d* (Rosenthal, 1991). Note that an important feature determining the suitability of effect sizes from the *r* and *d* family for meta-analytical research is their unitless nature, which enhances their comparability between individual studies

The data used as input for Application B, the agri-environmental policy programmes in the EU, allow the calculation of an effect size of the *d* family. The case study results give information about the behaviour of farmers in an 'experimental group' that consists of farmers participating in an agri-environmental programme, and in a 'control group' that includes farmers not participating in an agri-environmental programme. The structure of the data is thus similar to those in typical primary studies in the traditional fields of meta-analysis. Chapter 7, which is dedicated to Application B, gives a further explanation of the effect sizes of the *d* family.

Primary studies that report sufficient information for estimating effect sizes are desirable to any meta-analyst. Unfortunately, this information is not always given in primary empirical studies. Some studies may only report information about the statistical significance of the estimated relationship. Others may only provide information about the direction (the sign) of the relationship (Bushman, 1994; Rosenthal, 1991). Depending on the types of information available in the results of the primary studies, different statistical techniques are applied. This issue will further be elaborated upon in the following subsections.

5.3.2 Three different groups of techniques

In the following description of techniques for research synthesis, we want to distinguish between three different groups. The first group includes conventional statistical methods for meta-analytical research as they are applied in the traditional fields of meta-analysis, medical research, psychology and the natural sciences. Subsection 5.3.3 is concerned with the first group of techniques for research synthesis and gives a concise description of four different meta-analytical techniques, namely, a) vote-counting procedures, b) combining significance levels, c) combining effect size estimates and d) moderator analysis. Techniques c) and d) are employed in Application B, the agri-environmental policy programmes in the EU.

The second group of techniques describes meta-regression analysis, a tool that is mainly used in meta-analyses in the economic field. The popularity of performing meta-analyses within a regression framework may be due to the fact that conventional regression techniques are widely applied and are mostly used in empirical economic studies. The technique is well-known to economists, which increases their understanding and may reduce their scepticism about meta-analytical research in their field. Another reason for the suitability of meta-regression approaches to analysing economic issues is that regression analysis is an appropriate technique for taking into account the heterogeneity characterising individual observations, e.g., the elasticities obtained from different empirical studies in the meta-sample. Application C, the effects of agricultural income on land prices, gives an empirical example of a meta-regression analysis. A short explanation of meta-regression analysis is given in Subsection 5.3.4.

The third group of techniques consists of comparative research methods that do not belong to the pure statistical approaches, but to classification approaches. These techniques have the potential to handle data that are much more diverse and less precise, that do not have certain statistical properties and that are measured on a categorical or nominal scale rather than on a cardinal scale. In particular, we want to focus on rough set analysis, the technique that is employed in Application A, the co-operative agreements between farmers and water supply companies. However, other types of classification techniques will be mentioned as well. The classification techniques are introduced in Subsection 5.3.5.

5.3.3 Conventional statistical methods for meta-analysis

It has been mentioned above that the conventional statistical methods for meta-analysis are mainly applied in the traditional fields of meta-analytical research. It has, furthermore, been noted that research in the traditional fields has a different structure than in the economic sciences. Studies in the traditional fields are mainly concerned with the differences between two groups, which may be regarded as the reason for the evolution of the statistical methods explained in this subsection.

In general, the conventional statistical methods can be divided into two major approaches to meta-analysis. The first approach summarises information about the *significance* of an effect. This approach requires only information about the statistical significance of the estimated relationship or about the direction (the sign) of the relationship, and not about the actual magnitude of the effect. The second approach summarises and analyses the effect sizes themselves (Becker, 1994). This approach also demands information about the *magnitude* of an effect size. As mentioned in the previous subsection, we want to present four different conventional statistical methods for meta-analysis, namely a) vote-counting procedures, b) combing significance levels, c) combining effect size estimates and d) moderator analysis. Methods a) and b) investigate questions with the first approach, while methods c) and d) investigate those with the second approach. The following paragraphs give a concise description of the four different conventional statistical methods for meta-analysis.

a) *Vote-counting*

Basically, vote-counting procedures consist of counting the number of statistically significant research findings. Conventional vote-counting procedures divide the research findings into three categories: 1) statistically significant findings with the expected sign, 2) statistically significant findings with the unexpected sign and 3) insignificant findings. On the basis of pure counting, the label of the category with the largest number of findings would indicate the nature of the effect (Cooper, 1998). Although conventional vote-counting may give an initial impression of the nature of the effect, this technique needs to be handled with care. Conventional vote-counting does not include the sample sizes of the underlying primary studies. This implies that estimates based on larger sample sizes, i.e., estimates that have a lower variance and that are more robust, have the same weight as estimates based on smaller sample sizes. Conventional vote-counting has furthermore been criticised for its very low power if effect sizes are medium to small and if sample sizes are small.

More sophisticated vote-counting procedures are able to incorporate individual sample sizes. Moreover, they can provide confidence intervals for the percentage of significant results and can even come up with a Bayes estimate of the common effect size. They can hence provide an indication of the actual magnitude of the effect. The latter is, however, only possible if all the results of the underlying studies have the same direction (Bushman, 1994).

To summarise, vote-counting procedures should not be the first choice if sufficient information for the application of other meta-analytical techniques is available. They may be employed to give a descriptive impression of the theory under investigation. However, if possible, they should not be reported without employing a more sensitive meta-analytical procedure (Cooper, 1998). For more detailed information on vote-counting procedures, see Cooper and Hedges (1994a), Hunter and Schmidt (1990) and Hedges and Olkin (1985).

b) *Combining significance levels*

As in the case of vote-counting, combining significance levels does not require information about the actual magnitude of the effect, the effect size. The name of this meta-analytical method indicates that the data required from the underlying primary studies are significance levels, mainly provided in form of *p*-values. The advantage of this method over the vote-counting procedure is that it takes into account the sample sizes of the underlying primary studies and hence the robustness of the individual estimates (Cooper, 1998). The aim of this method is an examination of the existence of a particular effect. Research questions that are concerned with the magnitude of an effect cannot be addressed with this method.

It must be noted that meta-analytical methods that take into account information about the magnitude of an effect are superior to combining significance levels and hence also to vote-counting procedures. However, the latter two methods also have a number of advantages. They require only a limited amount of information and are easy to compute. Furthermore, combined significance tests are nonparametric, which means that the underlying data do not necessarily need to fulfil the strict assumption required for parametric models (Becker, 1994).

c) *Combining effect size estimates*

In contrast to the two methods just described, combining effect size estimates, as their name indicates, require that the underlying primary studies provide sufficient information about the actual magnitude of the effect, so that an effect size can be estimated. Combining effect size estimates additionally require a measure of the accuracy of the effect size, its estimated variance. The first step in this meta-analytical technique is the calculation of a common effect size estimator. This denotes the summation of the estimated effect sizes of the individual primary studies, weighted by their respective variances. The weighing scheme guarantees that effect sizes with a lower variance, i.e., effect sizes that are more robust, have a stronger influence on the value of the common effect size estimator (Van den Bergh et al., 1997). The common effect size estimator answers, on the one hand, questions about the statistical significance of the overall, summarised effect and, on the other hand, questions about the actual magnitude of the effect.

The second step in this technique includes a test on the homogeneity of the common effect size estimate. The homogeneity test investigates the hypothesis that the real effect sizes of all individual primary studies are equal. A rejection of this hypothesis gives rise to a question about the reasons for statistically significant variations between the individual effect sizes (Van den Bergh et al, 1997). This question may be answered with help from a moderator analysis, the meta-analytical technique described in point d). Application B employs the two steps of the combining effect sizes technique. The chapter dedicated to Application B, Chapter 7, gives a more precise description of this technique.

d) *Moderator analysis*[18]

Moderator variables are the factors that are associated with the variations in the magnitude of the effect sizes that have been established by the test on homogeneity (Rosenthal, 1991). A moderator analysis investigates whether particular moderator variables that have been predetermined by the researcher are indeed responsible for the variations among the individual effect sizes. The individual effect sizes of the meta-sample are grouped according to particular categories of the moderator variable under consideration. Subsequently, the new groups of individual effect sizes are again examined for homogeneity. In a moderator analysis, the homogeneity test investigates two different aspects. First, it tests the hypothesis that the effect sizes within a group are homogeneous. Second, it tests the hypothesis that the mean effect sizes between the different groups are homogeneous. If the first test still indicates heterogeneity within the groups, the application of a further moderator variable may be advisable. It is important to note that moderator variables in the type of moderator analysis described here can only be applied in a categorical form. Continuous forms of moderator variables can be employed in a meta-regression framework, which is described in Subsection 5.3.4. Application B in Chapter 7 also gives an empirical example of the moderator analysis described here. A more detailed description of this technique can be found in Chapter 7.

5.3.4 Meta-regression analysis

Basically, meta-regression analysis is a conventional regression analysis applied to aggregated data or effect size indicators. Most meta-regression analyses aim at explaining variations in former research results, or effect sizes such as elasticities. The dependent variable in a meta-regression analysis is the effect size, whose variation needs to be explained. The independent variables represent the differing characteristics of the underlying studies, comprising, for example, theoretical and modelling approaches, the structure of the data and spatial and temporal

[18] The moderator analysis described in this paragraph refers to a moderator analysis following the combining effect sizes method described in the previous paragraph. In general, the term ‘moderator analysis’ implies an analysis of variations in the effect size by means of moderator variables and hence also a meta-regression analysis. Meta-regression analysis is described explicitly in the following subsection.

characteristics. These mainly take the form of dummy variables, whose coefficients indicate the relationship between a specific study characteristic and the effect size. Continuous variables that may be included as independent variables in a meta-regression analysis are samples sizes[19] of the underlying studies or temporal variables, such as the time spans covered by the data in the underlying studies (Stanley and Jarrell, 1989).

It is often stated in the literature that the constant term in the meta-regression equation may be interpreted as the 'true' value of the parameter of interest, or, in other words, the 'true' value of the effect size (Stanley and Jarrell, 1989). This statement, however, needs some qualifications. The constant term in a meta-regression analysis captures the effects of the omitted categories in the meta-regression analysis. The constant term should hence be interpreted as the value of the effect size in a situation in which the conditions described by the omitted variables are at present.[20]

The preceding description of a meta-regression analysis focuses on explaining variations in effect sizes. There are, however, also regression approaches that are concerned with the significance and/or the sign of the effect sign. Discrete dependent variable models, such as logit and probit models, can be employed to investigate the factors that may determine the statistical significance and/or the sign of a particular effect size. As in the vote-counting procedures, the sample of effect sizes is divided into different categories containing, for example, either significantly negative, insignificant or significantly positive results. The groups, arranged in a logical order, then compose the dependent variable. The independent variables may be of the same structure and have the same function as in the meta-regression analysis described above. They aim at explaining the variances, i.e., the significance levels and signs, in the dependent variable.

Application C in the empirical part of this dissertation presents a meta-regression analysis that aims at explaining the variances in the magnitude of the effect size. A further description of meta-regression analyses is hence given in Chapter 8, which contains Application C.

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[19] Sample sizes may be included in relation to the detection of publication bias (Card and Krueger, 1995). Publication bias is one of the major methodological problems in meta-analysis and will be further described below.

[20] The way in which continuous variables, such as temporal variables, are incorporated into the meta-regression model is important for interpreting the constant term. There are different ways to include temporal variables in a meta-regression analysis, such as the first year of the data series in the underlying study, the first year plus the time span of the data series, the first year plus the last year of the data series or a trend variable. Different specifications of the temporal aspect lead not only to differences in the magnitude of the constant term but also to differences in the significance of the constant term.

5.3.5 Classification techniques

The classification techniques may not be focussed on meta-approaches alone. In the empirical part of this dissertation, we employ a type of classification technique, rough set analysis, to Application A, which has above been identified as a comparative analysis of case studies. However, classification techniques may also be applied to meta-approaches, i.e., in cases where summary statistics from different individual studies are investigated. The classification techniques presented here are non-parametric methods, which implies that the data being investigated do not have to fulfil particular statistical requirements, such as a normal distribution of the investigated population. Another advantage of these techniques is that the underlying data do not have to provide a certain minimum number of observations, implying that they are not dependent on a certain number of degrees of freedom.

Non-parametric classification techniques include rough set analysis, fuzzy set analysis, cluster analysis and neural networks (Nijkamp et al., 1999). Since the empirical part of this dissertation shows an example of rough set analysis, the following paragraph provides a concise overview of this technique.

Rough set analysis was developed in the early 1980s by Pawlak (1982, 1991). It generally serves to pinpoint regularities in classified data, to identify the relative importance of some specific data attributes and to eliminate less relevant ones, and to discover possible cause-effect relationships by logical deterministic inference rules (Van den Bergh et al., 1997). In recent years, rough set analysis has gained increasing popularity in the social and economic sciences, not only because of the advantages arising from its non-parametric character but also because of its ability to handle imprecise and qualitative data (Baaijens and Nijkamp, 2000). Impreciseness and uncertainty of information are well-known phenomena in environmental policy assessment since the goods concerned and their socio-economic utility are not directly identifiable or measurable. Uncertainty of information can arise for a number of reasons, such as an actual lack of information, the inaccuracy of available information or imperfect representation of the subject under consideration (Van den Bergh et al., 1997). This counts for various ways of collecting data, ranging from field observations to surveys and questionnaires. A number of rough set analyses have been carried out in the field of agricultural and environmental policy analysis. Nijkamp and Pepping (1997) have investigated differences in pesticide price elasticities, Nijkamp and Vindigni (1999) have performed a comparative analysis of the agricultural sector in different countries, and Nijkamp (2000) has studied the success and failure of soil remediation policies in the Netherlands. A more detailed description including technical information about rough set analysis is given in Chapter 6.

5.4 Problems Inherent in Meta-Analysis

Meta-analysis has not gone without criticism. There are three methodological problems that are inherent in meta-analysis (Florax, 2002a; Stanley, 2001; Wolf, 1986). The first critique is concerned with the heterogeneity of the individual studies included in a meta-analysis. This has often been referred to as the problem of comparing 'apples and oranges'. The second problem deals with selection and publication biases, which implies that the likelihood of sampling a study depends on the appearance of the effect size measure. The third criticism focuses on multiple sampling of effect sizes per individual study, which implies that some studies contribute more than one observation to the meta-sample. Multiple sampling involves two problems. First, there is the problem of dependency among observations in the meta-sample. Observations from the same study may be dependent because they are based on, for example, the same primary data set or analytical technique. The second problem is concerned with equally weighting the individual studies. If all observations in the meta-sample had the same weight, say one, studies that provided numerous estimates would have a stronger influence on the results of the meta-analysis than studies that contributed only a single or a few estimates to the meta-sample. The following paragraphs discuss the three critiques individually.

- *Heterogeneity*

Heterogeneity among studies occurs due to, for instance, differences in the type of data, in the quality of the data and research design, in the estimation technique applied, in the functional form and model specification and in the underlying theory (Florax 2002a). According to Lipsey and Wilson (2001), heterogeneity among study results has been criticised especially strongly in meta-analyses that aim to summarise and average a number or previous study results. It has been argued that a mean effects size or any other type of summary statistic resulting from a meta-analysis does not have meaning if it is aggregated over disproportional variations in study findings. However, meta-analyses in economics mainly focus on explaining the variations in study results. This implies that a certain amount of heterogeneity among the underlying studies is necessary in order to be able to determine the factors that have an influence on the significance and magnitude of the effect size under consideration. An adequate specification of the meta-model, which implies the appropriate identification and determination of moderator variables, should hence remove a significant part of the heterogeneity.

Along with the heterogeneity arising from the different characteristics of the underlying studies, there is inherent heteroscedasticity in the distribution of the effects sizes. The inherent heteroscedasiticty arises from the fact that effect size estimates are based on different sample sizes implying that variances, i.e., robustness, of the individual effects sizes may differ. Weighting the individual effect sizes with their respective standard errors could be an appropriate solution to this problem.

Unfortunately, information about standard errors, variances and/or sample sizes is not always provided by the underlying studies. An appropriate alternative is weighting with sample sizes. Another frequently applied method to deal with the problem of heterogeneity is to use a heteroscedasticity robust variance estimator (Florax 2002a).

- *Publication bias*

Publication bias may occur when the probability of a study being published is correlated with the sign and/or magnitude of the effect size. There are strong indications that primary studies with statistically significant results are more likely to be submitted, to be published or to be published more rapidly than studies with other results (Stanley, 2001; Sutton et al., 2000). Studies with insignificant or unexpected results, which may not be supported by the established literature, disappear into the files of the researcher. Publication bias is hence often referred to as the ‘file drawer’ problem. A meta-sample with publication bias may not be regarded as a true representation of the total population of studies.

The fact that only studies with ‘expected’ results tend to get published may affect the research behaviour of the empirical researcher. Goldfarb (1995) points out that a strong a priori expectation about the appearance of the effect size might lead to additional statistical estimations, for example, with varying model specifications, up to the point that the estimation results turn out as ‘expected’. The aggregated effect of this kind of research behaviour is another source of potential biases in primary studies.

The first approach for avoiding publication bias is profound and intensive literature retrieval. Along with a search for published literature in the official databases, such as EconLit, information about grey literature and unpublished research should be gathered. The Internet and electronic communication has increased the opportunities to trace grey literature and unpublished research. Working papers and research memoranda that are not meant for publication may be made available on the Web pages of economics departments or other research institutes. E-mail has facilitated personal contact between researchers, who may provide information about unpublished research on the issue under consideration.

If the meta-analyst is in the comfortable position of including published as well as unpublished studies in his or her meta-sample, the presence of publication bias may be tested and accounted for within the framework of the meta-analysis. In a meta-regression approach, the presence of publication bias would be proved by a significant coefficient of the dummy variable representing an unpublished study. In a meta-approach with conventional statistical techniques, the effect sizes of the group with unpublished studies and the group with published studies would result in significantly different average affect sizes. Other methods for detecting and correcting for publication bias are discussed in Florax (2002b); Sutton et al. (2000); Ashenfelter et al. (1999); Card and Krueger (1995); Hedges (1992).

Apart from publication bias, there may be other sources of selection bias, namely restrictive sampling over time, within a country or language zone or on the basis of a specific theoretical or modelling approach (Florax, 2002a).

- *Multiple sampling per individual study*

The first problem of multiple sampling per individual study is dependency among effect sizes. Studies report more than one estimate because they show, for instance, the results of different model specifications or compare estimates for different regions or different time periods. However, estimates sampled from the same study are likely to be based on the same original data, may be estimated by the same analytical technique and are certainly carried out by the same researcher or research team. Dependency among observations in the same sample may lead to inefficient estimates in the meta-regression analysis, which influences the validity of the hypothesis tests.

Dependency among the sampled observations can also be described as multidimensional autocorrelation, meaning that an observation can be influenced by multiple other observations within the same sample. This may occur within studies as well as between studies. As described above, within-study dependency among sampled observations is rather obvious. Between study dependency may occur if different studies use, e.g., the same data with respect to space and time or the same econometric technique in order to estimate the parameter of interest.

Although the dependency problem has been recognised as an important methodological pitfall of meta-analytical research, it has not yet received much attention in the literature. A number of studies, such as Espey and Thilmany (2000) and Espey (1996), have attempted to calculate the correlation among the error terms for each of the studies with multiple estimates in order to test for within-study dependency. Another approach to solving the dependency problem has been put forward by Florax (2002a), who suggests that within and between-study dependency in meta-regression analysis is similar to the multidimensional nature of spatial correlation among regions and countries. The application of spatial statistical techniques in order to analyse and correct for within and between-study dependency may hence be an appropriate method for dealing with the dependency problem. In the meta-regression analysis in Application C, we apply the approach proposed by Florax (2002a). A more detailed description of this approach is given in Chapter 8.

The second problem of multiple sampling per individual study, albeit not directly related to the dependency problem, deals with the equal weights that should be attached to each individual study. A study that supplies a large number of estimates to the meta-sample would dominate the results if no appropriate weighting scheme were applied. Several solutions to this problem have been proposed. A frequently-employed solution in the traditional fields of meta-analysis is the single value approach. The single value approach implies that each study is represented by one single value (Stanley, 2001). This single value may be the average measurement or the medium measurement per study, or it may be assigned by random selection

(Bijmolt and Pieters, 2001). It should be noted that the single value approach may be an appropriate solution for meta-analysis in the traditional fields, since the number of primary studies underlying the meta-analyses is usually higher than those in the economic sciences. Economic meta-analyses are often forced to make use of multiple estimates per study in order to maintain a reasonable amount of degree of freedom.

Bijmolt and Pieters (2001) have pointed out that the single value approach is not the most satisfactory approach, since it often fails to recover accurate measurements of the effect. The alternative to the single value approach is the complete set approach, which implies the inclusion of all the observations from the individual studies. As opposed to giving each observation the same weight, they propose two other solutions, namely, treating multiple measurements either as independent weighted replications or as dependent replications. The first solution provides a weighting scheme that guarantees that each study has the same weight in the meta-analysis regardless of the number of observations it contributes to the meta-sample. The second solution additionally accounts for dependency between estimates in the form of a nested error structure.

5.5 Conclusions

The increasing availability of documented research on agricultural and environmental economic policy questions has caused new methods of research synthesis to be developed in these fields. In particular, this chapter has identified three different forms of research synthesis: a) independent narrative literature review, b) comparative analysis of case studies and c) meta-analysis. This dissertation focuses in particular on the quantitative forms of research synthesis, forms b) and c). It has been identified that the structure of data used as input for the research synthesis determines which form to apply. A research synthesis is a comparative analysis of case studies if the individual observations are independent descriptions of case studies, i.e., if the information provided by the observations 'makes sense' when regarded individually, and if there are no aggregated data or summary statistics. On the other hand, a meta-analysis investigates the results of individual studies that are reported in aggregated form, that is, in the form of summary statistics.

There are a number of different techniques for performing meta-analysis or comparative analysis. Concerning meta-analysis, this chapter is divided between conventional statistical techniques and meta-regression analysis. Conventional statistical techniques for meta-analysis have widely been applied in medical research with the objective of summarising effect sizes over a number of primary studies and confirming (or rejecting) the actual existence of an effect. Meta-regression analysis mainly strives for a different objective, namely, explaining the differences among former study results, although conventional statistical techniques, such as the moderator analysis, may also, albeit in a limited way, account for differences in primary study results. Concerning comparative analysis, the chapter has focused on non-parametric classification methods, and in particular on rough set analysis. Here, the objective is to identify regularities in data and to discover potential relationships between the variables.

The following three chapters provide empirical applications of the analytical techniques presented in this chapter.

PART II

EMPIRICAL ANALYSES

CHAPTER 6

APPLICATION A:

CO-OPERATIVE AGREEMENTS FOR LIMITING AGRICULTURAL NITRATE POLLUTION

6.1 Introduction

Nitrogen is one of the primary nutrients required for plant growth, since it is an essential component of chlorophyll, the pigment responsible for the photosynthetic process. However, the increasing utilisation of manure and of other nitrogen-containing fertilisers in agricultural production during the past decades has led to increasing nitrate leaching, which contributes to serious environmental problems, such as the pollution of groundwater, eutrophication of surface waters, or the pollution of nature areas (Bijl et al., 1999).

The focus of this chapter is on nitrate pollution in groundwater used for producing drinking water. Along with their many negative effects on ecosystems and biodiversity, high nitrate levels in drinking water are assumed to cause two kinds of health problems: the blue baby syndrome (oxygen starvation in bottle-fed babies) and stomach cancer (Hanley, 1990; Chowdhury and Lacewell, 1996). In order to protect water consumers against the risk of these diseases, the European Commission (EC) in its Drinking Water Directive (established in 1989) and the World Health Organisation have defined a legal maximum threshold of 50 mg of nitrate per litre of drinking water. The guideline for nitrate in drinking water proposed by the EC is even more restrictive at 25 mg per litre (Fuchs, 1994). Whereas scientific evidence on the actual existence of a link between excessive nitrate levels and the above mentioned diseases is still controversial, water consumers may indeed favour pure and untouched groundwater as a source of drinking water (Hanley, 1990).

The economic characteristics of the nitrate problem and of co-operative agreements as policy alternative to such standard regulations as command-and-control policies, is explicated on several occasions in the previous chapters. Chapter 4 has mentioned that co-operative or voluntary agreements may enhance economic efficiency and environmental effectiveness by taking into account the knowledge of stakeholders located in the area where the environmental problem occurs and due to their flexibility for tailoring their measures against environmental pollution to local conditions. However, the effectiveness of co-operative agreements needs to be tested.

The co-operative agreements investigated in this chapter are between water supply companies and farmers in the German state of Bavaria. Water supply companies have to comply with the above mentioned European Drinking Water Directive. Especially in nitrate-sensitive areas with intensive agriculture, water supply companies find it difficult to deliver drinking water with less than 50 mg of nitrate per litre without using technical means to reduce the nitrate content. Whereas blending groundwater from contaminated wells with water from clean wells is a relatively easy option, purification by means of an installation for nitrate removal is a sophisticated technical process involving considerable cost. An important motivation for water supply companies to initiate co-operative agreements with farmers is therefore to avoid the risk of incurring future purification costs (Kuks, 1998), which is related to the Coase Theorem described in Subsection 4.5.2.

The first objective of this chapter is to assess the environmental effectiveness of co-operative agreements. The effectiveness of co-operative agreements is measured in terms of the development of the nitrate level in groundwater. The effect of co-operative agreements on groundwater quality is positive if the nitrate level shows a decreasing or, at least, a stabilising trend. As noted in Chapter 5, we utilise rough set analysis in order to assess the effectiveness of the co-operative agreements. Rough set analysis is a non-parametric method that assists in identifying regularities in classified data and generating so-called decision rules that may be used for policy evaluation and advice.

Rough set analysis is, however, plagued by a combination of methodological issues. The first issue that has not received much attention in applications of rough set analysis to empirical policy assessment deals with the categorisation of the data that is required for performing a rough set analysis. The second issue is based on the first issue and it is concerned with the potential loss of information due to the categorisation of the data. The second objective of this chapter is therefore to add to the existing literature on rough set analysis for policy assessment by addressing the two described methodological issues.

Regarding the first issue, the subsequent analysis compares three strictly-defined categorisation methods and assesses their respective effects on the final results. The comparison between the three categorisation methods may be regarded as a sensitivity analysis with respect to the method of data categorisation. The second issue is addressed by comparing the results of the rough set analyses based on the three different categorisation methods with the results of a probit analysis. In this comparison, we are particularly interested in the direction in which different factors affect the effectiveness of the co-operative agreements, i.e., the development of the nitrate level in groundwater.

This chapter is organised as follows. As an addition to the basic economic principles of agricultural pollution provided in Chapter 3, Section 6.2 reviews some further economic aspects of nitrate pollution. Section 6.3 extends the theoretical discussion on co-operative agreements in Chapter 4 by providing some empirical examples and descriptions of experiences from the literature, particularly focusing on co-operative agreements between farmers and water supply companies. Section 6.4 presents a concise description of the methodology of rough set analysis and of three categorisation methods. Section 6.5 provides a description of the data and of the influencing factors included in the analysis. Section 6.6 presents the results. This chapter concludes with a discussion and conclusions in Section 6.7.

6.2 Economic Aspects of Nitrate Pollution in Groundwater

Chapter 3 in the theoretical part of this dissertation identified nitrate pollution in groundwater as a negative externality of agricultural production. Water suppliers and farmers use groundwater resources in different ways. Whereas water suppliers take groundwater as input for production, farmers use the groundwater basin as a waste disposal facility. For both of these uses, groundwater is regarded as a common property resource, implying that exclusive property rights are not defined (Siebert, 1986). A concept that would properly apply to this particular situation is the Polluter Pays Principle (PPP) established by the OECD in 1972 (OECD, 1975). The PPP is also included in the European Nitrate Directive that states that "…*the costs of measures necessary to change current practices to reduce nitrate pollution should be borne by agricultural operators*" (European Communities, 2000, p. 41). However, the current distribution of costs and benefits involved in the abatement of nitrate pollution and in the establishment of co-operative agreements between water suppliers and farmers is not consistent with the PPP. Costs for purification and co-operative agreements are borne by water suppliers who, under German legislation, can in turn pass on their costs to the consumer. It has frequently been observed that the farming sector has been exempted from the PPP and has instead been subsidised in order to encourage the adoption of environmentally friendly farming practices for reducing the emissions of harmful substances, such as nitrate (Hanley et al., 1998). As has been discussed in Chapter 3, the subsidisation of environmentally friendly farming practices implies the production of positive externalities by farmers, namely the *improvement* of environmental quality.

Two important reasons for this mismatch between theory, claiming that nitrate pollution in groundwater is an external cost, and reality, indicating that the *improvement* of groundwater quality may be regarded as an external benefit, are pointed out by Tobey and Smets (1996). First, there is the problem that the agricultural sector is mainly characterised by non-point source pollution. It is difficult to determine who and what kind of activity has been responsible for which share of the total pollution. Furthermore, the severity of pollution does not depend only on the quantity of the harmful substance applied, but also on the time of application, the type of crop to which it is applied, the method of application and on the complexity of the underlying ecosystem, such as the soil type, the climatic circumstances or the hydrological system. Second, there is the aspect of competitiveness. Agriculture is a classical competitive sector with a large number of small producers who cannot influence the producer price. This implies that pollution abatement costs cannot be passed on to the consumer. Competitiveness may hence be affected. Diakosavvas (1994) shows in a study considering 23 countries and ten agricultural commodities that a country's net exports tend to fall due to environmental regulation. However, the general literature on international trade does not provide unambiguous evidence of a negative relationship between environmental regulations and competitiveness (Mulatu et al., 2001).

Costs involved in switching to environmentally friendlier farming methods may not only include costs for alternative machinery, additional land, or manure storage facilities, but also for remedying farmers' lack of knowledge of how to apply these methods. Conventional agricultural policy has stimulated farmers to adopt farming methods that intensify production. Total abatement costs may indeed be unbearable for family farms with limited human and financial resources, which are not only subject to environmental policies, but also to ongoing agricultural policy reforms. Co-operative agreements may be a proper instrument for raising farmers' awareness of environmental problems, for directly involving them in the policy process and for assisting farmers in adopting alternative production methods. The following section gives some examples of co-operative agreements.

6.3 Co-operative Agreements between Farmers and Water Suppliers

Co-operative or voluntary agreements were first established between governmental agencies and the industrial sector in order to reach certain environmental goals, such as the reduction of CO_2-, NO_X-, and SO_2-emission, or the reduction of CFCs in refrigerators and spray cans. The increasing popularity of co-operative agreements can mainly be ascribed to their communicative and interactive character. Governmental agencies and the polluting industries negotiate for the most appropriate solutions to reach the environmental target, mainly in combination with governmental subsidies for technical innovations (Sunnevåg, 2000). Because of the joint responsibility concerning the content of the agreement, the industrial sector is more likely to accept and to be well disposed towards reaching the environmental goal. Furthermore, the interactive character creates more flexibility, which in turn provides the opportunity to find cost-effective solutions that are tailored to the local conditions, and reduces the time span between formulation of the policy goal and policy implementation (Segerson and Miceli, 1998).

Segerson and Miceli (1998) distinguish between two types of co-operative agreements: the stick approach and the carrot approach. In the stick approach, participation in the co-operative agreement is stimulated by threats to implement more stringent legislation if the environmental target agreed upon is not reached. In the carrot approach, participation is encouraged by incentive payments such as subsidies or cost-sharing programmes for investments in pollution abatement technologies.

There are a number of examples of voluntary environmental agreements between the agricultural sector and governments. One of them is the agri-environmental policy programme of the EU, Application B, which is investigated in Chapter 7. Another example is the Conservation Reserve Programme in the United States. Voluntary agreements between the agricultural sector and another private sector, such as the drinking water industry, are, however, rare. In fact, direct agreements between farmers and water suppliers are uncommon in all EU Member States. They can mainly be found in Germany and the Netherlands and to a lesser extent in France. Germany, with over 400, has the largest number of agreements. This is more than 80% of the total number of agreements in the EU. However, in Germany, the distribution of co-operative agreements is not well-balanced. They can mainly be found in four of the 16 Bundesländer, viz. North-Rhine Westphalia, Bavaria, Hesse and Lower Saxony (Heinz et al., 2001).

Apparently, a number of factors can promote or hamper the establishment of co-operative agreements between water supply companies and farmers in the EU. An important promoting factor is that drinking water stems from well-contained and compact groundwater resources, e.g., well-determined groundwater protection zones. This limits the spatial dispersion of pollution such that the cause of the pollution can be determined unambiguously. Furthermore, the water supply companies' ability to finance the co-operative agreements, the willingness of the farmers to adopt pollution-reducing practices and public preferences for pure and untreated water are supporting factors for the establishment of co-operative agreements. Important hampering factors are a reliance on command-and-control measures in some countries and a lack of enforcement of environmental legislation in other countries. Moreover, the existence of other local, regional or national agri-environmental programmes in some parts of the EU may crowd out local initiatives from water supply companies (Heinz et al., 2001).

Existing co-operative agreements between farmers and water suppliers cannot strictly be categorised into one of the two types mentioned above. Most of them are a combination of both, which means using background threats of stronger legislation and providing incentive payments for applying environmentally improved practices. In fact, as is pointed out by Wu and Babcock (1999), citing Davies et al., successful voluntary agreements must be based on a proper statutory framework (i.e., background legislation), need to have a clear and measurable environmental target and must provide substantial financial incentives. The importance of financial incentives is also underlined by Anders Norton et al. (1994), who state, referring to conventional wisdom, that farmers would not be willing to voluntarily adopt pollution abatement methods without a subsidy compensating for the costs of these methods and any revenue losses. However, positive incentives need not only be of financial nature. They may also be provided in the form of payments-in-kind, such as technical assistance and teaching programmes or supervised study groups and workshops, where farmers get the opportunity to acquaint themselves with environmentally sound farming methods. An important aspect of organised teaching programmes is that they increase farmers' awareness and understanding of the nitrate problem. Farmers might realise that pollution abatement practices may also increase on-farm environmental quality. In such cases, farmers may even be willing to adopt pollution abatement practices without full compensation for costs and revenue losses (Anders Norton et al., 1994).

Theoretical economic analyses of voluntary agreements in agriculture have been carried out by Segerson and Miceli (1998) and Wu and Babcock (1999). Segerson and Miceli's objective was to find out whether voluntary agreements lead to efficient environmental protection as compared to mandatory legislation. They show that along with background threats and financial incentives, the structure of the bargaining power between the regulator and the firm plays an important role in the agreement about the level of abatement. In particular cases where the regulator has all of the bargaining power, the equilibrium level of abatement under the voluntary agreement might be the first best level, i.e., higher than the level under mandatory legislation. Wu and Babcock have analysed the relative efficiency of voluntary programmes compared to mandatory programmes. They point out that important comparative advantages of voluntary programmes are the reduction of enforcement costs and the avoidance of duplicate private effort. As a comparative disadvantage, they mention, that voluntary programmes may involve large government expenditures that may cause deadweight social losses.

The present chapter does not attempt to provide a theoretical analysis in a mathematical framework. It focuses instead on an empirical examination of data collected for a number of existing co-operative agreements. The method used in this analysis is based on rough set theory, which is explained in the following section.

6.4 Rough Set Analysis

A general introduction to rough set analysis has been given in Chapter 5. Subsection 6.4.1 extends the information provided in Chapter 5 by offering a more detailed explanation of rough set analysis. The introduction to this chapter has pointed out two combined methodological issues inherent in rough set analysis. The first issue is concerned with the categorisation of the data required for performing a rough set analysis and the second deals with the loss of information that results from the categorisation. Subsection 6.4.2 considers the issue of categorisation and describes the three categorisation methods used in the rough set analysis in this chapter.

6.4.1 Description of rough set analysis

Understanding the functioning of rough set analysis requires the clarification of a number of terms (Pawlak, 1991; Van den Bergh et al., 1997; Baaijens and Nijkamp, 2000). Broadly speaking, rough set analysis consists of three major components: 1) sorting, 2) attribute reduction and 3) derivation of decision rules. First, the sorting procedure can concisely be described as follows. The observations or cases to be sorted form a finite set of objects (x), called universe U. Each object is characterised and identified by a finite set of attributes Q, with the attributes q taking on different values in their domain. The data referring to the objects and attributes are ordered in an *information table*. Objects can also be described in terms of any subset of attributes $P \subseteq Q$. Objects that are described with the same attribute or subset of attributes are called *P-indiscernible*, meaning that they fall into the same class (the *equivalence* class) with respect to the attributes concerned, i.e., they can no longer be distinguished by different attribute values. The equivalence classes are also called *P-elementary sets*, which is the most precise classification possible, on the basis of the available information.

Second, attribute reduction refers to the elimination of redundant information, which means retrieving a minimal set of attributes R that supplies the same quality of classification as the original set of attributes P. The minimal sets of attributes R are called *reducts*. The most important characteristic of a reduct is that additional attributes do not lead to a more accurate classification of the objects, whereas the elimination of an attribute does lead to a less accurate classification. It is important to note that an information table can have more than one reduct. The intersection of all reducts, or, in other words, an attribute that appears in all minimal sets is defined as the *core*. The core contains the attributes that are most important in the information table and that are most relevant for the classification of the objects.

Third, the derivation of decision rules requires the partitioning of the attributes into decision and condition attributes. A decision attribute is a single attribute that reflects the phenomenon to be studied. In fact, the decision attribute is analogous to the dependent variable and the condition attribute to the independent variables in standard regression analysis. It is, however, important to mention that the relationship between the decision attribute and the condition attribute is not the same as those between the dependent and the independent variables within a regression framework. Whereas the estimated relationship between a dependent and an independent variable indicates a potential causal relationship between the two variables, the relationship between a decision and a condition attribute indicates the frequency at which a certain category of the decision attribute occurs in certain categories of the decision attributes. Decision rules may more accurately be described as conditional statements that are expressed in the form of "if-then" statements. Decision rules may either be exact or approximate. An exact rule declares that a particular combination of categories of the condition attributes results in only one particular category of the decision attribute. An approximate rule states that a particular combination of categories of the condition attributes implies more than one category of the decision attribute. The quality of the decision rule is indicated by its *strength*. The strength of a rule represents the number of observations or cases that are in accordance with that rule. Decision rules are the most relevant part of rough set analysis because they indicate the direction in which the investigated condition variables impact the condition variable.

The following subsection is concerned with the categorisation of the data required to perform a rough set analysis.

6.4.2 Categorisation of the data

The categorisation of data implies the transformation of quantitative, continuous data into categorical information. The process of transforming a continuous variable into a finite number of intervals is called discretisation, and it is regarded as one of the most problematic issues in taxonomic experiments (Van den Bergh et al., 1997). The most popular criticism of discretisation concerns the loss of information involved.[21] The categorisation of a continuous variable is not considered problematic if the discretisation occurs on the basis of concrete underlying theoretical factors. Unfortunately, this condition is not fulfilled in many cases. The categorisation of data is also called binning. Accordingly, categories are also called bins.

In most of the previously performed rough set analyses in economics, the categorisation was performed in a rather ad hoc manner, which means by visually inspecting the data and dividing them into more or less equally-sized categories. A point of concern with this type of categorisation is that it does not take into account the effect of the determined bin widths and intervals on the final result. In the rough set analysis in this chapter, we apply three different strictly defined categorisation methods and compare them with respect to their influence on the final results. In other words, the analysis in this chapter includes a sensitivity analysis with respect to the method of data categorisation. The three different categorisation methods are a) equal-frequency binning, b) equal-interval binning and c) the entropy-based method. These methods can be briefly described as follows.

a) Equal-frequency binning

Categorisation according to equal-frequency binning implies an even distribution of the attribute values over a predetermined number of bins. This type of binning is also known as histogram equalisation (Witten and Frank, 2000).

[21] Kohavi and Sahami (1996) point out that discretisation may also be viewed as a form of knowledge discovery, since it may be able to reveal critical values in a continuous domain. This, however, requires that predetermined critical values exist, which is rather uncommon in the economic sciences.

b) Equal-interval binning
In this categorisation method, the bin widths are equalised. The whole range of attribute values is divided by the number of bins, so that equal bin widths can be constructed. The attribute values are then sorted into the respective bins.

c) Entropy-based method
Entropy-based methods create classes with the lowest possible level of entropy, i.e., classes that group the most similar data together, so that the data are represented in the most compact and organised way. In the analysis in this chapter, entropy-based categorisation is carried out by the rough set software package ROSE II (Predki et al., 1998; Predki and Wilk, 1999), which incorporates entropy-based discretisation methods.

The literature on categorisation methods and data mining describes equal-frequency and equal-interval binning as naïve discretisation methods, since these methods may aggravate the problem of the loss of important information. Entropy-based categorisation methods have been proven to be more reliable (Kohavi and Sahami, 1996; Fayyad and Irani, 1993). However, especially in the case of relatively small data sets with a limited number of observations, the entropy-based methods often result in a very uneven distribution of observations across the different categories, which in turn may influence the results of the rough set analysis. Section 6.5 gives an overview of actual bin widths and bin sizes from the three different categorisation techniques.

6.5 Data and Attributes

The data used in the analysis stem from a survey that was held among water supply companies and municipalities in Bavaria, Germany, about co-operative agreements with farmers in the year 2000.[22] The addresses of the water supply companies and municipalities that offer co-operative agreements to farmers were obtained from the State of Bavaria. The list of addresses contained 139 water supply companies and municipalities. Each of them received a questionnaire, and 75 were returned. However, because of incomplete questionnaires and missing information we ultimately made use of 40 questionnaires. The analysis is hence based on 40 observations. The following gives a description of the attributes that characterise the observations.

[22] The survey is part of the EU research project "Co-operative agreements in agriculture as an instrument to improve the economic efficiency and environmental effectiveness of the European Union water policy" (Heinz et al., 2001).

Decision attribute:

Development of nitrate content in groundwater

The decision attribute is the development of the nitrate content in groundwater. This attribute is derived from the question in the survey answered by the water supply companies about the effects of the co-operative agreement on drinking water quality. It is categorised into two classes. Class 1 contains all those cases in which, at the time of the survey, the nitrate levels in groundwater show a decreasing or at least stabilising trend, or, in other words, in which the co-operative agreement indicates a positive effect. Class 2 contains the cases that still show increasing nitrate levels and cases where a change in the development of the nitrate level is not yet recognisable, i.e., cases in which the effect of the co-operative agreement is negative.

Condition attributes:

1) Year of foundation

Depending on geological conditions, rainwater needs a certain amount of time to percolate through the soil into the groundwater reservoir. Residuals of nitrogen containing substances, such as mineral fertiliser and manure, are transported into the groundwater reservoir by the percolating rainwater. The effects of a policy aiming at the reduction of nitrogen surpluses should hence also become visible only after a number of years. The earlier the year of foundation of the co-operative agreement, the more likely a positive policy effect.

2) Total area under contract

The size of the total area under contract is supposed to have a positive relationship with the policy effect. A larger area under contract implies a larger catchment basin where the restrictive measures of the co-operative agreement apply.

3) Land use: arable

Arable land lacks permanent and complete soil cover, which means that residuals of nitrogen containing fertiliser are washed out more easily. A high share of arable land would hence likely be associated with a negative policy effect.

4) Number of participating farmers

This condition attribute may give an indication of whether the number of participating farmers plays a role in the effect of the co-operative agreement.

The following attributes refer to the contents of the co-operative agreements. We, therefore, want to call them the policy attributes. Condition attributes 5), 6) and 7) describe the restrictions farmers face when entering into an agreement. The restrictions are ordered according to their severity. It should be mentioned that all co-operative agreements described by the 40 observations include restrictions on the use of mineral fertiliser and liquid manure, such as the amount and time of application.

The restrictions on fertilisation are therefore not explicitly formulated as an attribute. Condition attributes 8) and 9) describe the number of restrictions and the amount of payments respectively.

5) Restriction 1: set-aside

This restriction implies that farmers are supposed to take (some) land located in the area under consideration out of production. It is the most severe restriction offered by a co-operative agreement. This factor is binarily formulated. It takes 'yes' if the co-operative agreement includes set-asides and 'no' if not.

6) Restriction 2: permanent grassland

This restriction requires farmers to use the land under agreement as permanent grassland. It includes prohibiting the conversion of grassland into arable land and mandating that arable land be converted to grassland. This factor is also binarily formulated. It takes 'yes' if permanent grassland is included as a restriction, and 'no' otherwise.

7) Restriction 3: soil cover

The third restriction imposed on farmers is the maintenance of permanent soil cover. This restriction includes measures such as intercropping or the cultivation of catch crops. It does not prescribe actual changes in agricultural land use, but demands additional effort during the main crop's vegetation period. This attribute is also binary. It takes 'yes' if the co-operative agreement includes soil cover and 'no' otherwise.

8) Number of restrictions

Some co-operative agreements include no other restrictions than the general restriction on fertilisation. Others include one, two or all of the restrictions described in condition attributes 5), 6) and 7). This attribute hence comprises four different categories: 1 = no extra restriction, 2 (3) (4) = one (two) (three) additional restrictions. This condition attribute may also be regarded as an indicator of the variability or possibility of choices offered by the co-operative agreement. We hypothesise that a combination of more restrictions has a positive influence on the nitrate level in groundwater.

9) Expenses

This factor describes the expenses the water supply company has to bear to support the co-operative agreement. It is measured in expenses per hectare. It also indicates the compensation payments that farmers with land under co-operation receive. It is hypothesised that higher payments induce greater efforts to reduce nitrate leakage.

Table 6.1 summarises the condition attributes, shows their observed ranges of values and indicates their hypothesised association with the development of the nitrate level in groundwater.

Table 6.1: Condition attributes with ranges and expected signs

	Condition attribute	Range	Expected sign
1	Year of foundation	1989 - 2000	-
2	Total area under contract	7 ha - 1500 ha	+
3	Land use: arable land	0 % - 100 %	-
4	Number of participating farmers	1 - 77	?
5	Restriction 1: Set aside	yes/no	+
6	Restriction 2: Permanent grassland	yes/no	+
7	Restriction 3: Soil Cover	yes/no	+
8	Number of restrictions	0 – 3	+
9	Expenses per hectare	51 - 8003 Euro	+

The sign, shown in the last column of Table 6.1, indicates the hypothesised direction of the effect, i.e., "+" for a decreasing nitrate level in groundwater (a positive policy effect) and "-" for an increasing nitrate level in groundwater (negative policy effect), for increasing attribute values.

Condition attributes 1), 2), 3), 4) and 9) are continuous variables. These variables need to be classified according to the three categorisation methods described in 6.4.[23] Table 6.2 shows the qualitative classes and the ranges of the five condition attributes for all three categorisation methods.

Table 6.2 indicates that the class intervals as well as the number of observations in each class differ significantly between the three catgorisation methods. By definition, equal-frequency binning results in the most even distribution of observations over the four classes. The other two catgorisation methods result in rather unbalanced distributions of the observation across the different classes. The information in the table is illustrated in the following two figures. Figure 6.1 shows the distribution of the observations across the four classes according to the three categorisation methods. Figure 6.2 depicts the bin widths of the four categories of the three categorisation methods.

Table 6.2: Classes and ranges of attributes for three different categorisation methods

[23] With the help of the agglomerative hierarchical clustering procedure, we determined that four is the most appropriate number of classes for most of the condition variables. Agglomerative hierarchical clustering indicate the stepwise combination of objects into clusters, starting with a situation in which the number of objects is equal to the number of clusters. The optimal number of clusters is determined on the basis of a similarity measure that measures the average cluster distance (for detailed information on clustering procedures, see Hair et al., 1998)).

Qualitative classes for attributes		**Equal-frequency binning**		**Equal-interval binning**		**Entropy-based categorisation**	
1) Year of foundation	1	1987-1991	(10)	1987-1990	(6)	1987-1989	(3)
	2	1992-1995*	(9)	1991-1993	(10)	1990-1991	(7)
	3	1996-1997*	(11)	1994-1996	(14)	1992-1998	(23)
	4	1998-2000	(10)	1997-2000**	(10)	1999-2000	(7)
2) Total area under contract (ha)	1	< 55	(10)	< 375	(27)	< 9	(1)
	2	60-185	(10)	376-750	(8)	9-59	(9)
	3	187-537	(10)	751-1125	(3)	60-70	(3)
	4	600-1500	(10)	1126-1500	(2)	71-1500	(27)
3) Arable land use (%)	1	0-50	(10)	0-25	(4)	0-45	(8)
	2	51-64	(10)	26-50	(6)	46-50	(2)
	3	65-79	(10)	51-75	(16)	51-92	(26)
	4	80-100	(10)	76-100	(14)	93-100	(4)
4) Number of participating Farmers	1	1-11	(10)	1-19	(22)	1-4	(5)
	2	12-15	(10)	20-38	(10)	5-12	(8)
	3	17-35	(10)	39-58	(3)	13-65	(24)
	4	37-77	(10)	59-77	(5)	66-77	(3)
9) Expenses (Euro per hectare)	1	< 74	(10)	< 219	(27)	< 6	(1)
	2	76-130	(10)	220-444	(9)	6.1-26	(5)
	3	138-253	(10)	445-659	(2)	67-546	(31)
	4	254-2557	(10)	> 660***	(2)	547-2557	(3)

Figures in brackets are the number of observations in a class.
*) In order to keep all observations from 1996 in one class, the class sizes are slightly different.
**) The total range of years of foundation comprises 14 years, such that the years cannot be equally divided across 4 categories. We hence constructed categories comprising 3 and 4 years respectively.
***) 2557 was not taken into account in the determination of the intervals since it would have led to empty classes. It is, however, included in the number of observations for this category.

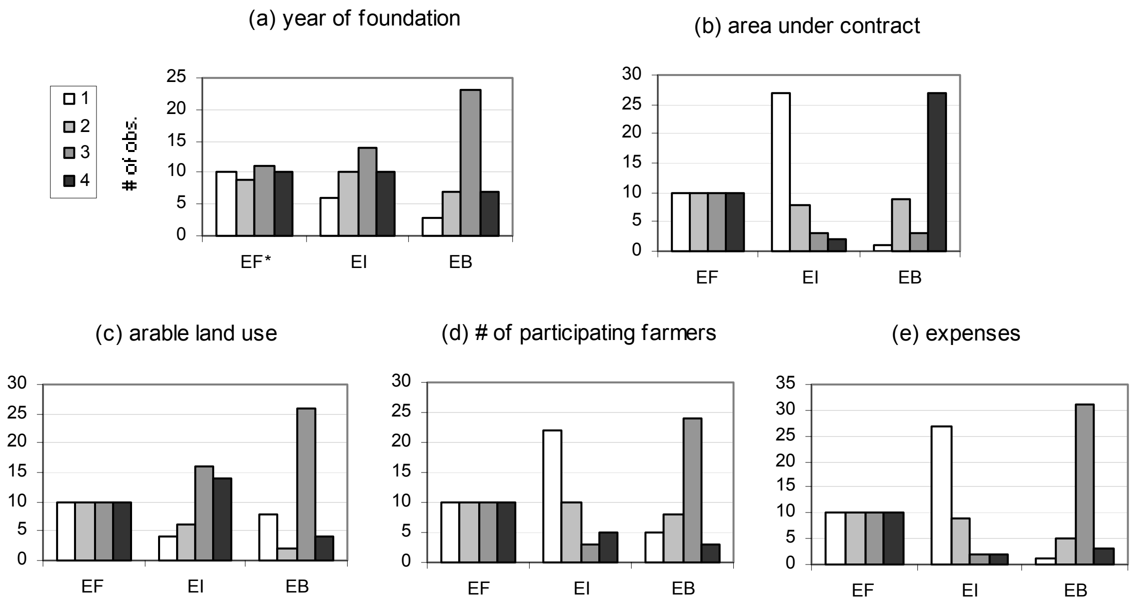

Figure 6.1: Distribution of the observations across the four classes according to the three categorisation methods (EF: equal-frequency binning (EF*: remind remark*) in Table 6.2), EI: equal-interval binning, EB: entropy-based method)

By definition, equal-interval binning results in equal widths of the four categories. This is shown in Figure 6.2. Figure 6.2 indicates that the bin widths differ considerably for equal-frequency binning and the entropy-based method, which is particularly obvious in Panel (b) and (e), where the fourth category has the widest intervals. It should be noted that the distribution of the observations across the four categories (Figure 6.1) may influence the actual procedure of the rough set analysis. The influence of differences in bin widths (Figure 6.2) may only become obvious when the results are interpreted. The following section shows whether the different categorisation methods do indeed have indeed an influence on the results of the rough set analysis.

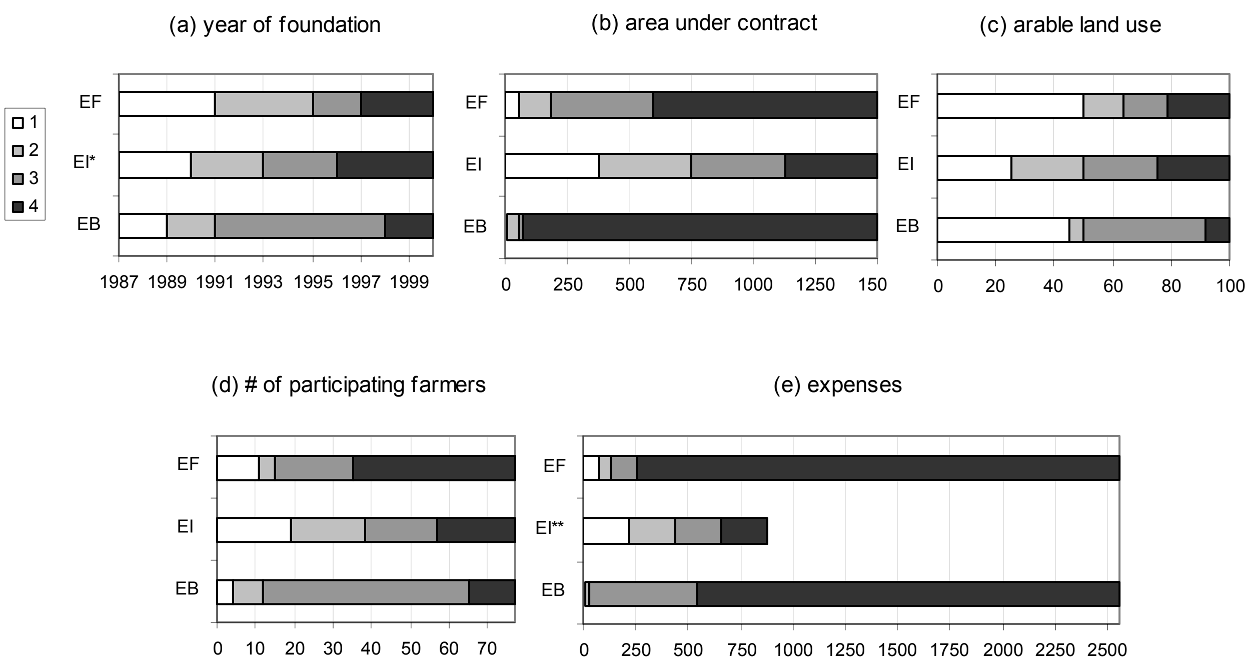

Figure 6.2: Bin widths of the three categorisation methods (EF: equal-frequency binning, EI: equal-interval binning (EI*/** remind remark *)/**) in Table 6.2), EB: entropy-based method)

6.6 Results

The first question to be answered in the presentation of the results is whether all the information about the 40 observations given by the nine condition attributes is necessary for a consistent decision algorithm. This procedure refers to the component of attribute reduction described in Section 6.4, which results in the identification of minimal sets or reducts. Minimal sets contain no redundant information. They represent a reduced set of attributes that provide the same classification quality of the decision attribute as the original set of condition attributes. Nijkamp (2000) points out that a theoretically perfect solution would occur if the attribute reduction results in only one minimal. The reason for this is that the fewer possibilities for minimal sets, the higher the 'predictive power' of the information (Pawlak, 1991).

The attribute reduction based on the three categorisation methods identifies different numbers of minimal sets. On the basis of equal-frequency binning, eleven minimal sets, including either four or five condition attributes, can be found. The attribute reduction on the basis of equal-interval binning and the entropy-based method results in only two minimal sets, each with four and five or seven condition attributes respectively. Considering the aforementioned notion about the number of minimal sets, it can be concluded that, on the basis of the data considered in this chapter, equal-interval binning and the entropy-based method lead to a more satisfactory attribute reduction than equal-frequency binning. In other words, the former two categorisation methods seem to have greater predictive power with regard to the considered information than the latter one. The actual minimal sets are given in Appendix 6a.

One interesting and informative way of representing the minimal sets is a frequency table that shows the frequencies with which the different condition attributes appear in the minimal sets. The frequency of appearance gives an indication of the importance of some of the condition attributes relative to others. The frequency table is shown in Table 6.3.

Table 6.3: Frequency of appearance of condition attributes in minimal sets

Condition attribute	Equal-frequency binning *frequency*		Equal-interval binning *frequency*		Entropy-based categorisation *frequency*	
	#	%	#	%	#	%
1) Year of foundation	11	100	2	100	2	100
2) Area under contract	6	54.55	--	--	--	--
3) Arable land use	6	54.55	2	100	2	100
4) Number of part. farmers	8	72.73	2	100	2	100
5) Restriction 1: set aside	2	18.18	--	--	1	50
6) Restriction 2: perm. grassland	5	45.45	1	50	1	50
7) Restriction 3: soil cover	3	27.27	--	--	1	50
8) Number of restrictions	5	45.45	1	50	1	50
9) Expenses	4	36.36	--	--	2	100

Table 6.3 shows that the relative frequency of appearance of the different condition attributes differs between the three categorisation methods. As defined in Section 6.4, condition attributes that appear in all minimal sets (i.e., a frequency of 100%) are the cores, which have the most explanatory power relative to the other condition variables. The condition attribute 'year of foundation' appears to be a core attribute in all three categorisation methods. It can thus be considered important for the classification of the decision attribute, i.e., the development of the nitrate level in groundwater, and it may give an indication of the environmental success of co-

operative agreements over the long/short term. Along with ‘year of foundation’, the condition variables ‘arable land use’ and ‘number of participating farmers’ are identified as cores for equal-interval binning and the entropy-based method. Furthermore, it is interesting to note that only one policy attribute[24] is identified as a core, namely ‘expenses per hectare’ in the entropy-based method. Additionally, all other policy attributes seem to be relatively less important than the remaining condition attributes in all three categorisation methods.

It is also interesting to look at the direction in which the condition attributes influence the development of the nitrate level in groundwater. The direction of the impact can be derived on the basis of the decision rules that have been defined above in the form of “if-then” conditional statements. The rule induction based on equal-frequency binning, equal-interval binning and the entropy-based method results in 16, 18, and 15 decision rules, respectively. It must, however, be noted that not all decision rules are of equal quality and hence equally important and reliable. A parameter that indicates the quality of the decision rules is their *strength*. Some generated decision rules have a very low strength, which implies that they are only supported by a small number of observations. In Table 6.4, we report only those decision rules that have a strength greater than 4, which implies that the rules are based on at least 4 observations. Table 6.4 reports the actual ranges of the categories instead of their labels.

The importance of the condition attribute ‘year of foundation’ becomes obvious in Table 6.4. This condition attribute appears more frequently in the decision rules than the other condition attributes. It appears, furthermore, that rule induction on the basis of the entropy-based method results in the most decision rules of a strength equal to or greater than 4. Additionally, the rules have on average greater strength than the decision generated on the basis of the other two categorisation methods. It is also striking that two condition attributes, namely, ‘number of participating farmers’ and ‘restriction 1: set aside’ do not appear at all in the decision rules given in Table 6.4.

When investigating the decision rules, it is important to consider the *combination* of attributes in the rules. The decision rules that include ‘year of foundation’ do not always show unambiguous results. Regarding the ‘year of foundation’ individually, one might conclude that the actual value of this condition attribute does not seem to matter since a positive development of the nitrate level in groundwater appears over the whole range of possible foundation years. However, in combination with the other attributes, the differences in year of foundation lead to some interesting results. From a theoretical point of view, earlier years of foundation should more likely result in positive developments of the nitrate level in groundwater. Rule a1 says that recently established co-operative agreements may lead to positive developments of the nitrate level if the agreement includes the restriction ‘permanent

[24] As defined in Section 6.5, the policy attributes are condition attributes 5) - 9).

grassland'. Rule a3 says that co-operative agreements established less than ten years ago also have a positive effect on groundwater quality if an additional restriction, soil cover, is included in the agreement. The implication of these two rules are supported by Rule b2, which says that recently established co-operative agreements have a positive influence on groundwater quality if the agreements include two additional restrictions, though these have not been explicitly determined. Rule a2 implies that co-operative agreements that have been in operation the longest lead to improvements in the groundwater quality even if the additional restriction on soil cover is not included in the agreement. This interpretation of Rule a2 coincides with that of Rule b1 and, to some extent, also with that of Rule c2. Furthermore, Rules a4, b5 and c6 all indicate that co-operative agreements established less than ten years ago and without any additional restrictions do not positively influence groundwater quality.

Table 6.4: Decision rules

	I F									THEN	
Rule	Year of foundation	Total area under contract	Arable land use	Number of participating farmers	Restriction1: Set aside	Restriction2: Permanent grassland	Restriction 3: Soil cover	Number of Restrictions	Expenses (Euro/hectare)	Development of nitrate level	Strength
a) Equal-frequency binning											
a1	98-00					yes				pos.	5
a2	87-91						no			pos.	7
a3	92-95	80-100					yes			pos.	4
a4	96-97							0		neg.	4
b) Equal-interval binning											
b1	87-90						no			pos.	4
b2	97-00							2		pos.	4
b3			0-25							pos.	4
b4								2	<219	pos.	6
b5	94-96							0		neg.	4
c) Entropy-based method											
c1		71-1500						2		pos.	7
c2	90-91									pos.	7
c3									6.1-26	pos.	5
c4		9-59				yes				pos.	4
c5			0-45							pos.	8
c6	92-99							0	67-546	neg.	6

Regarding the percentage of arable land use, another conclusion can be drawn from the decision rules. Rules b3 and c5 indicate that lower percentages of arable land use (<25% and <45%, respectively) have a potentially positive relationship with the development of the groundwater quality. This result is in accordance with the hypothesised situation explained in Section 6.5. Another interesting result revealed by Rules b4, c3 and c6 is that higher payments do not necessarily lead to positive developments in groundwater quality (higher payments are supposed to induce greater efforts on part of farmers). However, on the basis of the results presented here, it is too early to conclude that money does not matter for stimulating environmentally sound farming methods. Finally, the decision rules (a3, c1 and c4) do not lead to any unambiguous conclusion about the potential effect of the total area under contract on the development of nitrate levels in groundwater.

Another way of presenting and interpreting the results of the rule induction is to consider each condition attribute individually. Here, the individual condition attributes are counted according to the value at which they appear in the decision rules. In this case, all decision rules are taken into account, not just the ones with strengths greater than 4. The results are shown in Table 6.5.

Table 6.5 can be interpreted as follows. Consider the condition attribute ‘year of foundation’ for the equal-frequency binning method. Eight (four) observations appearing in the decision rules describe a situation in which a co-operative agreement established between 1987 and 1991 (1992 and 1995) is associated with a positive development in groundwater quality. The situation in which a co-operative agreement is associated with a negative development in groundwater quality can be derived accordingly. Regarding the ‘positive’ situations in comparison with the ‘negative’ situations, it may be concluded that under equal-frequency binning, the condition variable ‘year of foundation’ indicates that longer established co-operative agreements are more likely to be associated with positive developments in groundwater quality. However, a comparison between the three categorisation methods shows that this result does not appear with all methods. Whereas under the entropy-based method, the results approach those given form equal-frequency binning, the results generated with equal-interval binning are very different from those of the other two methods. The same is true for condition attributes 2), 4), 5), 7) and 9). Approximately conforming results from the three categorisation methods can be observed for condition attributes ‘arable land use’, ‘restriction 2: permanent grassland’ and ‘number of restrictions’.

The results for ‘arable land use’ indicate a tendency to associate lower shares of arable land in total agricultural land with positive developments in the groundwater quality. Regarding the attribute ‘restriction 2: permanent grassland’, it may be concluded that a co-operative agreement including this restriction is more likely to have a positive effect on groundwater quality. Finally, concerning the attribute ‘number of restrictions’, it seems that a larger number of restrictions is advisable in order to obtain a positive effect on groundwater quality. The results of the three latter indicators confirm the hypothesised relationships given in Section 6.5.

Table 6.5: Frequency of appearance of condition attribute values in the decision rules

Equal-frequency binning			**equal-interval binning**			**entropy-based method**		
1) year of foundation								
	pos.	neg.		pos.	neg.		pos.	neg.
87-91	8	-	87-90	4	-	87-89	1	-
92-95	4	2	91-93	5	3	90-91	7	-
96-97	-	3	94-96	2	7	92-99	1	7
98-00	-	-	97-00	5	2	99-00	3	-
2) total area under contract								
	pos.	neg.		pos.	neg.		pos.	neg.
< 55	3	2	< 375	-	-	< 9	-	-
60-185	4	2	376-750	-	3	9-59	5	-
187-537	5	4	751-1125	-	1	60-70	-	-
600-1500	4	4	1126-1500	-	-	71-1500	7	-
3) arable land use								
	pos.	neg.		pos.	neg.		pos.	neg.
0-50	2	-	0-25	4	-	0-45	8	-
51-64	2	2	26-50	-	-	46-50	-	2
65-79	2	2	51-75	4	2	51-92	1	4
80-100	-	2	76-100	2	1	93-100	-	1
4) number of participating farmers								
	pos.	neg.		pos.	neg.		pos.	neg.
1-11	-	-	1-19	2	5	1-4	-	3
12-15	3	-	20-38	2	3	5-12	-	-
17-35	3	-	39-58	-	-	13-65	1	2
37-77	-	-	59-77	2	1	66-77	3	-
5) restriction1: set aside								
	pos.	neg.		pos.	neg.		pos.	neg.
yes	-	2	yes	-	-	yes	-	-
no	3	2	no	-	-	no	-	-
6) restriction 2: permanent grassland								
	pos.	neg.		pos.	neg.		pos.	neg.
yes	5	-	yes	-	-	yes	4	-
no	2	-	no	-	6	no	1	-
7) restriction 3: soil cover								
	pos.	neg.		pos.	neg.		pos.	neg.
yes	4	-	yes	2	1	yes	-	-
no	7	-	no	4	-	no	-	-
8) number of restrictions								
	pos.	neg.		pos.	neg.		pos.	neg.
0	-	4	0	-	-	0	-	6
1	-	2	1	2	2	1	1	2
2	5	-	2	10	-	2	7	-
3	-	-	3	-	-	3	-	1
9) expenses per hectare								
	pos.	neg.		pos.	neg.		pos.	neg.
<74	2	2	<219	2	4	<6	-	-
76-130	-	-	220-444	-	-	6.1-26	5	1
138-253	-	-	445-659	-	-	67-546	1	7
254-2557	-	-	660-2557	2	1	547-2557	-	-

In order to gain insight into the potential loss of information that results from the categorisation of the data, we want to compare the results of the rough set analysis with those of a probit analysis. The results of the probit analysis are shown in Table 6.6.

Table 6.6: Results of the probit model

	variable*	coefficient	p-value
	Constant	113.424	0.459
1	year of foundation	-0.056	0.464
2	total area under agreement	-0.002	0.108
3	arable land use	-0.012	0.379
4	participating farmers	0.050	0.057
6	restriction 2: perm. grassland	1.693	0.127
7	restriction 3: soil cover	1.186	0.214
8	number of restrictions	-0.885	0.228
9	expenses per hectare	0.000	0.938
Likelihood ratio test		*12.622*	*0.126*
Number of observations: 40			

*) Because of near collinearity between the constant and the variable 'restriction 1: set aside', we had to excluded this variable from the analysis, which prevents us from comparing it with the results obtained in the rough set analysis.

Table 6.6 shows that most of the estimated coefficients of the explanatory variables are insignificant. This result is, however, not surprising, considering the relatively low number of observations (degrees of freedom) for a probit model. The only coefficient that is significant at a 10-percent level belongs to the variable 'number of participating farmers'. Coefficients that approach the 10-percent significance level belong to the variables 'total area under agreement' and 'restriction 2: permanent grassland'. The condition attribute 'number of participating farmers' in the rough set analysis has been identified as a core attribute for equal-interval binning and the entropy-based method (see Table 6.3). In the minimal sets based on equal-frequency binning, this attribute appears with a frequency of 73 percent, i.e., it may also be considered important for the classification of the decision attribute. Concerning the relative importance of the variable/attribute 'number of participating farmers', the results of the rough set analysis and of the probit analysis are corresponding. This attribute does not appear in any of the decision rules with strengths greater than 4. The condition attributes 'total area under agreement' and 'restriction 2: permanent grassland' are not identified as core attributes in the rough set analysis. On the other hand, other variables that appear to be important in the rough set analysis ('year of foundation' and 'arable land use') do not yield significant results in the probit analysis.

As mentioned above, the relatively low number of observations in the probit model let us expect that the coefficients will have low significance levels. However, it is still interesting to investigate the direction of the effects in the probit model and whether they correspond to the results of the rough set analysis.[25] For this exercise,

[25] Note that the coefficients of the probit analysis do not show the marginal effects of the variables, but only the direction of the effect.

we compare the results of the probit analysis with the information provided in Table 6.5. Table 6.7 gives an indication of the extent to which the direction of the effects generated by the two types of analyses correspond.

Table 6.7: Correspondence between results of the rough set analysis and the probit model

	attribute/variable*	equal-frequency	equal-interval	entropy-based
1	year of foundation	+	+/-	+
2	area under contract	+	-	-
3	arable land use	+	+/-	+
4	participating farmers	+/-	+/-	+
6	Restriction 2: perm. grassland	+	+	+
7	Restriction 3: soil cover	-	-	+/-
8	number of restrictions	-	-	-
9	expenses per hectare	+/-	-	-

*) Remind that we could not include attribute 5 'restriction 1: set aside' in the probit model

Legend:
+ : corresponds well (both analyses show the same direction of the effect)
+/- : comparison not possible because information in Table 6.5 does not show a clear direction of the effect
- : does not correspond (the two analyses show different directions of the effect)

A first inspection of Table 6.7 shows that the rough set results based on equal-frequency binning and the entropy-based method correspond better to the results of the probit analysis than the rough set results based on equal-interval binning. It is striking that only one attribute/variable, i.e., 'restriction 2: permanent grassland', exhibits corresponding results for all three categorisation methods. The attributes 'year of foundation' and 'arable land use' show corresponding results for two of the three categorisation methods.

Regarding the second methodological issue in rough set analysis, the potential loss of information, we can suppose the following on the basis of the data analysed in this chapter, based on the assumption that the probit analysis exploits the data better since it makes use of the whole range of data. Of the variables that are (nearly) significant at a 10-percent level ('number of participating farmers', 'total area under agreement' and 'restriction 2: permanent grassland') only 'restriction 2: permanent grassland' shows unambiguously corresponding results for all three categorisation methods. For the attribute 'number of participating farmers', only the result based on the entropy-based method corresponds to that of the probit analysis. On the basis of the other two categorisation methods, no clear direction of the effect can be determined. For the attribute 'total area under agreement', only the result based on equal-frequency binning corresponds with that of the probit analysis. Furthermore, the results based on equal-interval binning most often do not show a clear direction of the effect. To summarise, it seems that the categorisation of the data in the rough set analysis leads to a loss of information, which becomes particularly obvious in the results based on equal-interval binning.

6.7 Discussion and Conclusions

This chapter has dealt with two objectives. The first objective was to assess the environmental effectiveness of co-operative agreements by means of rough set analysis. The second objective was to contribute to the existing literature on rough set analysis for policy assessment by addressing two methodological issues, namely, the influence of different categorisation methods on the final results and the potential loss of information due to the categorisation of the data. Let us first concentrate on the second objective. Rough set analysis is an alternative tool for analysing categorised data. Although rough set analysis does not lead to the determination of strong statistical relationships, it may be able to determine factors that lead to certain values of a variable under consideration, in this case the positive or negative development of the nitrate level in groundwater. Rough set analysis hence goes beyond a simple narrative description of the data, but is less rigorous than pure statistical analysis.

On the basis of the data analysed in this chapter, different methods of data categorisation influence the results of the rough set analysis. It must be emphasised that the ‘safest’ method of data categorisation is on the basis of predetermined, theoretical grounds. This condition is, however, not always given, so that other categorisation frameworks need to be applied. The three different categorisation methods investigated in this analysis (equal-frequency binning, equal-interval binning and the entropy-based method) lead to different numbers of minimal sets, which theoretically implies differences in the information’s predictive power. However, although the rule induction based on the three different categorisation methods leads to different numbers of decision rules with strengths greater than 4 and to different combinations of condition attributes within the rules, it does not generate contradictory results between the rules based on the three methods. Regarding the frequency of appearance of the individual condition attributes in all decision rules, the rough set analyses based on the three categorisation methods do not show corresponding results for all condition attributes.

In comparing the rough set results with the results of the probit analysis, it appears that the rough set results based on equal-frequency binning (the entropy-based method) correspond to a lesser (stronger) extent to the results of the probit analysis. Assuming that the probit analysis better exploits the data since it includes all individual observations, it seems that categorising the data in the rough set analysis leads to a loss of information. It furthermore appears that, on the basis of the data analysed, equal-interval binning seems to entail the greatest loss of information.

With respect to the first objective, the following conclusion may be drawn on the basis of the data investigated in this chapter. A result that appears equally strong for all three rough set analyses based on the three categorisation methods as well as the probit analysis indicates a positive relationship between the attribute/variable ‘restriction 2: permanent grassland’ and the development of groundwater quality. The results from the decision rule induction of the rough set analysis show that this attribute seems to be particularly important in combination with the attribute ‘year of foundation’. The condition attribute ‘year of foundation’ appears to be an important attribute for the determination of the development of the nitrate content of groundwater. It is identified as a core attribute in all minimal sets and it appears most frequently in the generated decision rules. Our interpretation of the decision rules regarding ‘year of foundation’ leads to the following conclusion about the potential long/short-term impacts of co-operative agreements. Co-operative agreements that were established ten to fifteen years ago seem to have a positive influence on groundwater quality even without any additional restrictions but the general ones on fertiliser use, such as the amount and time of application. Furthermore, if the agreements include additional restrictions such as ‘permanent grassland’ or ‘soil cover’, they may have a positive effect on groundwater quality even in the shorter term, i.e., over less than ten or even five years. However, the rules explicitly point out that without any additional restrictions, a short-term beneficial effect from the co-operative agreements is very unlikely. Another attribute/variable that shows an equally strong effect on the results based on two of the three categorisation methods and the probit analysis is ‘arable land use’. The results indicate that smaller shares of arable land use with respect to total agricultural land use are more likely to lead to decreasing nitrate levels in groundwater, which is in accordance with the hypothesised relationship.

Appendix 6a. Minimal Sets

a) Minimal sets (reducts) based on equal-frequency binning

1: {perm grassland, soil cover, year, area, farmers}

2: {set aside, number of restrictions, year, area, farmers}

3: {soil cover, number of restrictions, year, area, farmers}

4: {set aside, perm grassland, year, area, arable}

5: {perm grassland, year, area, arable, expenses}

6: {number of restrictions, year, area, arable}

7: {perm grassland, year, arable, farmers}

8: {number of restrictions, year, arable, farmers}

9: {perm grassland, soil cover, year, expenses, farmers}

10: {number of restriction, year, expenses, farmers}

11: {year, arable, expenses, farmers}

b) Minimal sets based on equal-interval binning

1: {perm grassland, year, arable, farmers}

2: {number of restrictions, year, arable, farmers}

c) Minimal sets based on the entropy based method

1: {year, arable, set aside, perm grassland, soil cover, expenses, farmers}

2: {year, arable, expenses, farmers, number of restrictions}

CHAPTER 7

APPLICATION B:

AGRI-ENVIRONMENTAL POLICY PROGRAMMES IN THE EUROPEAN UNION

7.1 Introduction

Agri-environmental policy programmes were introduced by the European Commission along with the MacSharry reform of the Common Agricultural Policy in 1992. The reasons for the evolution of this type of policy programmes have been described explicitly in Chapter 2 of this dissertation. To summarise, agri-environmental policy programmes have been created, among other reasons, because of the increasing pressure that intensive agricultural production has put on the environment and because of the changes in land use in agricultural and rural areas during the 1980s. The function of farmland as the main input for agricultural production that secures the food supply has gradually lost its importance. Instead, farmland as a provider of environmental amenities, such as wildlife habitats and scenic and cultural venues for recreational purposes, has become an increasing public concern and can hence be viewed as a positive externality of (extensive) agricultural land use (Bromley and Hodge, 1990). Environmental amenities have the characteristics of a public good, and because of the lack of a market price, farmers' decision-making does not take the production of amenities into account (Brouwer and Slangen, 1998). Agri-environmental policy programmes as formulated by the European Commission seek to internalise the positive externalities of extensively used farmland by offering compensation payments for the income losses farmers may suffer when switching from intensive to extensive farming practices. The compensation payments should obviously reflect the value of the public good provided by farmers.

The European Agri-environmental policy is a very diverse and broad instrument that should be sufficiently flexible to take into account differences in geographical conditions, agricultural production systems, and rural traditions within the territory of the European Union. Because of these differing regional circumstances, it is obvious that the elaboration and implementation of the policy programmes take place on national, regional or even local levels, resulting in a large number of different implementation strategies. It is thus necessary for this policy to be administered on different levels of government. Given this wide variety of implementation strategies, a significant problem for policy makers is the difficulty of carrying out cross-national comparisons of policy effectiveness and the difficulty of evaluating the economic efficiency of the policy measures (Buller, 2000).

Against this background, this chapter provides a framework for research synthesis of case studies investigating the environmental effectiveness of agri-environmental policy programmes. In Chapter 5, the empirical analysis in this chapter was identified as a meta-analysis based on identically performed case studies in various regions of Europe. The main focus of the analysis in this chapter is on the identification of factors that may influence the performance of agri-environmental policy programmes. These factors may be either related to specific policy measures or to general agricultural conditions. The performance of the agri-environmental policy programmes is measured in terms of three agri-environmental indicators, namely, the use of nitrogen fertiliser, livestock density and the share of grassland area.

Two major research questions regarding the environmental aspects of agricultural land use are considered. One is concerned with the assessment of the environmental effectiveness of agri-environmental policies in the European Union. Based on a meta-analytical research design, the second component of this chapter deals with a methodological ‘experiment’. We investigate the research potential of analysing aggregated secondary data when original primary data are not available.

This chapter is organised as follows. Section 7.2 gives some further details of the agri-environmental policy programmes in the European Union. Section 7.3 summarises the most important points about agri-environmental indicators, which were described explicitly in Chapter 4. Furthermore, it provides a description of the indicators used in the analysis in this chapter. Section 7.4 briefly describes the EU research project that provided the case studies and offers a detailed description of the data used in the analysis. As introduced in Chapter 5, the analysis in this chapter makes use of effect size estimates applied to conventional statistical techniques for meta-analysis, combining effect size estimates and moderator analysis. The basic ideas behind these methods were provided in Chapter 5, and are further elaborated upon in Section 7.5. Section 7.6 reports the results and Section 7.7 provides some conclusions and recommendations.

7.2 The EU Agri-environmental Programme in Detail

The EU agri-environmental policy programme, in formal terms EC Council Regulation 2078/92, is one of the three accompanying measures of the 1992 CAP reform for stimulating the restructuring of the agricultural sector.[26] It is concerned with the implementation of special programmes to support and encourage farmers to introduce or continue using agricultural production methods consistent with the requirements of environmental protection and with the maintenance of characteristic landscape elements in the countryside. It is hence not only a framework for the stimulation of environmentally sound agriculture, but also for the multifunctionality and originality of rural space in Europe (Buller, 2000).

The EU agri-environmental policy is a co-financed instrument, which means that Member States can apply for co-funding of up to 50% and even up to 75% for Objective 1 regions[27]. The financial source for the accompanying measures is the European Agricultural Guidance and Guarantee Fund (EAGGF). The amount of money spent on the measures is rapidly increasing compared to traditional EAGGF expenditures, such as the crop or animal sector. However, the amount of money the EU spends on agri-environmental programmes is still less than 4% of total CAP expenditures (Buller, 2000). Obviously, the total amount of money spent on agri-environmental programmes is higher than this since, as mentioned above, the national governments also contribute to financing the programmes, which again indicates the mixture of administrative levels at which the policy is applied. With regard to the differences in policy compliance, participation in European agri-environmental policy programmes is voluntary for farmers. Member States are, however, obliged to implement such programmes. It is thus the first common European framework for national policies in the agri-environmental field (Brouwer and Lowe, 1998).

As mentioned above, the agri-environmental policy is a very diverse and broad instrument. To be precise, the policy includes about 2200 distinct measures incorporated in around 127 programmes. *Programmes* can be described as the way national or regional governments implement the policy, whereas *measures* are the specific agri-environmental actions introduced at a local level as components of national or regional programmes (Biehl, 1999). The European Commission has established a number of aid schemes that should be considered by Member States applying for financial aid. The aid schemes are described in Article 2.1 and 2.2 of the Regulation. They are shown in Table 7.1.

[26] As mentioned in Chapter 2, the other two accompanying measures are the early retirement scheme for farmers (Regulation 2079/92) and the afforestation programme for agricultural land (Regulation 2080/92) (Buller 2000, Soufi and Tuddenham, 1995, Brouwer and van Berkum, 1996).

[27] Objective 1 regions are those whose development is lagging behind in the sense that their per capita GDP has been less than 75% of the Community average over the past 3 years.

Table 7.1: Scheme objectives eligible for aid under Regulation 2078/92

Article 2.1 of Regulation 2078/92: Scheme objectives eligible for aid	
a	To reduce substantially the use of fertilisers and/or plant protection products; or to maintain the reductions already made; or to introduce or to continue with organic farming.
b	To change, by means of other than those referred to in (a), to more extensive forms of crop, including forage production; or to maintain extensive production methods introduced in the past; or to convert arable land into extensive grassland.
c	To reduce the number of sheep and cattle per forage area.
d	To use other farming practices compatible with the requirements of protecting the environment and natural resources, as well as maintaining the countryside and landscape; or to rear animals or local breeds in danger of extinction.
e	To ensure the upkeep of abandoned farmland or woodlands.
f	To set aside farmland for at least 20 years with a view to use it for the purpose of the environment, in particular for the establishment of biotope reserves of natural parks or for the protection of hydrological systems.
g	To manage land for public access and leisure activities.
Article 2.2 of Regulation 2078/92	
Training and demonstration projects for farmers.	

Source: CEC, 1992

The table indicates that the aid schemes comprise a wide range of agricultural practices promoting environmentally friendlier ways of farming. Alongside this variety of agri-environmental measure, there are also different strategies for implementing them. Buller (2000) distinguishes between four broad models of implementation. First, there are the targeted or zonal measures that aim at specific landscape types, natural regions or farming systems and at farmers located in particular zones. Examples of this type of measure are the Environmentally Sensitive Area (ESA) schemes in Denmark and the United Kingdom. Targeted or zonal measures are applied in most of the Member States. Second, there are wide horizontal schemes that cover whole nations or regions addressing certain eligibility criteria, such as grassland in the ‘Prime à l'herbe’ in France. A third type of implementation strategy is a broad regulatory framework that generally consists of a basic initial payment to participating farmers and a number of additional aid schemes requiring further restrictions and correspondingly higher payments. The Irish Rural Environmental Protection Scheme (REPS) is an example of this type of implementation strategy. Fourth, there are measures that focus on specific actions, such as the conversion and maintenance of organic farming, the protection of local breeds in danger of extinction, or training and demonstration projects for farmers. In general, it can be observed that schemes that demand changes in agricultural techniques involve higher payments than those focussing on the maintenance of existing extensive practices.

The EC has also proposed a categorisation of the aid schemes into five groups: i) organic farming; ii) farming with environmental improvements; iii) maintenance of low intensity systems; iv) non-productive land management; and v) training and demonstration projects. Preferences for specific schemes among the Member States appear to vary significantly. For example, Mediterranean countries tend to favour aid schemes for non-productive land management, which can be seen as a complementary source of income for farmers. Belgium, Denmark and Italy distinguish themselves from other Member States by allocating large proportions of their 2078/92 budget to organic farming, whereas Sweden and the Netherlands are in favour of training and demonstration projects (Buller, 2000).

By April 1997, 1.3 million contracts had been signed. This reflects around 18% of farms and 17% of total Utilisable Agricultural Area (UAA) in the EU (Buller, 2000). The fact that the number of farms is slightly higher than the area under contract shows that there is a tendency for small-scale farmers to participate in the programmes.

It should be mentioned that environmental concerns are not the only objective of Regulation 2078/92. Article 1 of the Regulation establishes three major goals: first, accompanying the changes that were to be introduced under the CAP reform in 1992; second, contributing to the Community's policy objectives regarding agriculture and the environment; and third, contributing to providing appropriate income for farmers (CEC, 1992). The first goal refers to the basic purposes of the 1992 CAP reform, namely the reduction of overproduction and of the financial burden, the reduction of market support measures and the introduction of a system of direct payments. The second goal addresses growing concern about the negative effects of agriculture on the environment such as water pollution, biodiversity loss and landscape change. It is, furthermore, the first effort to comply with the Maastricht Treaty that requires environmental policy to be integrated into all other EU policies. The third goal is concerned with the maintenance and protection of extensive farming practices, not only against intensification but also against agricultural decline and withdrawal (Buller, 2000).

In light of the global liberalisation of agricultural trade, the last goal of Article 1 of Regulation 2078/92 is an especially critical factor, since it may be interpreted as a justification for continuing the funding and subsidisation of European agriculture that is disguised as 'green' CAP (Buller, 2000). Nevertheless, agri-environmental support payments to farmers are acceptable according to the General Agreement of Tariffs and Trade (GATT) on agriculture. The WTO member countries agreed upon a reduction in domestic agriculture support measures by 20 per cent between 1995 and 2000 with respect to the support level in 1986-88. This reduction only refers to the so-called Amber Box support measures, which have the most disturbing effect on agricultural production and hence also on trade. A typical example of an Amber Box support measure is price support, which gives farmers direct economic incentives to expand or reduce their production. Agri-environmental policies belong to Green Box support measures. These measures are meant to have only a very small effect on production and trade, since the payments are supposed to be totally decoupled from production. Other examples of Green Box measures are general services, such as research or pest and disease control, domestic food aid and compensation payments for natural disasters. There are also Blue Box support measures, which provide payments on the basis of a fixed number of hectares or head of livestock in the frame of production limiting programmes (Silvis and van Rijswick, 1999).

Besides the criticism of hidden subsidisation and diversity of implementation strategies that hamper cross-national comparison of scheme effectiveness, a further critical remark may be made about the agri-environmental policy programmes in the EU. In many cases the environmental policy target of the programmes is far too broad and not adequately identified, such that potential positive effects on the environment cannot be properly evaluated (Buller, 2000). Realising the importance of critical points of agri-environmental policymaking, the EC has shifted emphasis towards the environmental objective, the second goal of Regulation 2078/92. In order to manifest these changes legally, the EC introduced a new tool in 1999, namely, the *Integrated Rural Development Regulation*, or, in formal terms, EC Council Regulation 1257/99. The new regulation integrates not only Regulation 2078/92, but also other rural measures such the Less Favoured Area scheme. In this new regulation, income support to farmers is no longer mentioned, and environmental goals are clearly specified for farmers who want to participate in agri-environmental policy programmes (Lowe and Baldock, 2000).

7.3 Agri-environmental Indicators

Agricultural sustainability has been identified as the overall policy objective of agricultural and agri-environmental policy making. Chapter 4 (Section 4.2) of this dissertation points out that indicators are effective tools for the operationalisation of sustainable development. Agricultural sustainability indicators may take the form of a set of strategies that describe particular changes in farming practices. An appropriate framework for studying agricultural sustainability indicators is the Driving Force-State-Response framework developed by the OECD (OECD, 1999). Driving forces are the factors that induce changes in environmental quality. The state-indicator gives a picture of the actual condition of the environment. The Response refers to the reactions of policy-makers, interest groups within society and other stakeholders to the state of the environment.

In Chapter 4, the indicators used in the current empirical application were described as Driving Force indicators that can inform us about the behaviour of farmers as a result of (non-)participation in agri-environmental policy programmes. The indicators used in the current analysis describe changes in agricultural practices, in particular, a) the use of mineral fertiliser, b) livestock density and c) grassland per

Utilisable Agricultural Area (UAA).[28] The selected indicators do not say anything about the actual state of the environment. An important criterion for selecting a Driving Force indicator of the behavioural type is its reliability, which implies that the impact of particular agricultural practices must be well known and scientifically proven (Andersen et al., 1999). The relationship between the agricultural practices serving as indicators in the current analysis and environmental quality is described in several scientific studies. Andersen et al. (1999) give a concise literature overview of these relationships, which can be summarised as follows.

a) *Mineral nitrogen fertiliser*

Excessive use of nitrogen fertiliser can change the botanical composition of grassland by favouring particular species over others. This, in turn, harmfully influences specific bird populations that use grassland as a breeding and feeding habitat. Furthermore, intensive nitrogen fertilisation increases the nitrogen stock in the soil, which results in a rate of nitrification that is higher than the nitrogen demand of the current crop. As a consequence, the surplus nitrogen will leach into groundwater.

In the current analysis, the indicator ‘mineral nitrogen fertiliser’ in measured in kg per hectare and is assumed to have a negative relationship with the state of the environment. A decreasing value of the indicator is therefore preferable.

b) *Livestock density per UAA*

A large amount of livestock per agricultural area is equivalent to high levels of manure and other forms of organic fertiliser. High levels of organic fertiliser are related to nitrate leaching into the groundwater. However, the actual relationship between livestock density and environmental quality has been found to be bell-shaped. The bell-shaped relationship implies that livestock densities that are either too high or too low result in a degradation of the traditional ecological system. In our case, the second half of the bell-shaped curve is of importance, which implies that livestock densities have to be reduced in order to improve environmental quality.

In the current analysis, the livestock density indicator is measured in total livestock units (LU) per hectare UAA. We hypothesise a negative relationship with the state of the environment, implying that decreasing livestock density is favourable for the environment.

[28] The indicators used in the current empirical application are the same as in the EU research project that provides the input data for the analysis. The research project developed 12 different indicators based on 9 particular agricultural practices. For the current analysis a significant minimum amount of systematic and common data is needed. Since not all of the 12 indicators comply with this requirement, we were forced to employ only three of them. Our choice of indicators is hence solely based on data availability.

c) *Grassland area per UAA*

In comparison with arable land, grassland has many environmental advantages. First of all, the loss of nitrogen under grassland is significantly lower than under arable land. Since ploughing accelerates the mobilisation of nitrate, it is favourable to prevent the conversion of grassland into arable land. Furthermore, the maintenance of extensive grassland is desirable, because not only its intensification but also its abandonment negatively affects the variety of faunal and floristic species found upon it. Finally, the creation of grassland is an ideal measure for the prevention of soil erosion through wind and water.

In the empirical analysis of this chapter, the grassland indicator is measured as the percentage of grassland per UAA.

7.4 Input Data: Case Studies of an EU Project

For the analysis in this chapter, case study results from a project considering the implementation and effectiveness of agri-environmental schemes in the European Union are used (Schramek et al., 1999).[29] The information from the case studies that is relevant for the analysis in this chapter describes the average change rates of the three agricultural indicators introduced in the previous section over a five-year period (1993-1997). The data for calculating the average change rates were obtained by interviewing individual farmers in the different case study areas on the basis of identical questionnaires. The interviewed farmers are classified into two groups. On the one hand, there are farmers who are eligible for and participating in agri-environmental programmes. On the other hand, there are farmers who are also eligible but not participating. Comparing the behaviour of participating farmers to that of non-participating farmers may give an indication of the environmental impact of the agri-environmental programmes offered in the case study areas.

The subdivision of the interviewees into participants and non-participants may essentially be interpreted as a quasi-experimental research design. Quasi-experiments have the same components as experiments, which are treatments, treatment and control units and outcome measures, but they do not randomly assign the units in the experiments for estimating the effect of the treatment (Cook and Campbell, 1979). In the case under consideration, participating farmers act as the treatment group and non-participating farmers as the control group. The non-randomisation lies in the fact that participation in agri-environmental programmes is voluntary, which means that the participating farmers themselves have chosen to undergo the treatment. It is thus possible that participating farmers have different characteristics than farmers who do

[29] The EU project has the contract number FAIR 1 CT95-274 and concerns the effectiveness of agri-environmental schemes established under EC Council Regulation 2078/92.

not participate. According to Brotherton (1991), farmers' participation in agri-environmental programmes is driven, on the one hand, by 'scheme factors' (e.g., payments, scheme duration, voluntary nature) and, on the other hand, by 'farmer factors' (e.g., age, education, dependency on farm income, information environment).[30]

Although the present research set-up cannot be considered a randomised experiment, it is interesting to analyse the behavioural differences between participating and non-participating farmers. The difference between the two groups can be interpreted as the difference between a policy-on and a policy-off situation. Many studies on the environmental effects of agri-environmental policies assume that agricultural intensification would continue and subsequently lead to further decline in environmental quality. However, given the current and upcoming reforms in agricultural policy, the validity of this assumption is hard to predict (Hanley et al., 1999).

Table 7.2 summarises the results of the change rates analyses carried out in the EU research project for the three selected indicators. Expected and significant results are those where the respective change rates have the anticipated sign (negative for nitrogen fertiliser and livestock density, positive for grassland) and where the change rate for participating farmers is significantly larger than the change rate for non-participating farmers.

Table 7.2 shows that the number of expected and significant results of the change rates for the tree indicators is rather limited. At a 5%-level, two out of nine results are significant for nitrogen fertiliser, one out of 13 results is significant for livestock density, and for grassland no significant result is found. The dominance of insignificant results might be due to the fact that sample sizes of the two groups in the individual case study areas are small, which increases the probability of an Type-II error (accepting the null-hypothesis although it may be false). Statistical significance is influenced by two effects, namely, the magnitude of the estimated effect and the sampling error around the estimate. The latter is entirely a function of sample size.

With help from the technique of effect size estimation and combination, we artificially lower the variance of the case study results, since it is based on statistical summary indicators rather than on the original observations. By estimating the size of the effect in each case study and pooling these estimates across the case studies, the analysis produces synthesised effect estimates with considerably more power than the individual case studies (Lipsey and Wilson, 2001). In the subsequent analysis, we will therefore test whether the average change rates of participating and non-participating

[30] A method for correcting for the self-selection bias is Heckman's two-step estimation procedure (Green, 2000). In the first step, the selection mechanism, i.e., the characteristics of the farmers who participate in the programme, would be determined. In the subsequent step, the estimated parameters of the first step would be used to estimate a corrected parameter of the actual policy effect. However, since we employ secondary/aggregated data in this chapter and since we do not have access to the original data, it is not possible to apply Heckman's two-stage estimation procedure in our analysis.

farmers with respect to the three indicators are indeed significantly different from each other, notwithstanding that analysis of the original data often leads to insignificant results.

Table 7.2: Results of the change rate analyses of the EU research project

Indicator	number of case studies	expected and significant sign[1)]	unexpected and significant sign	insignificant sign
nitrogen fertiliser	9	- Sahagun (ES), 5% - Larisa (GR), 5% - Wetterau (GER), 10% - Cambrian Mountains (GB), 10%		- Devon Countryside (GB) - Rhoen (GER) - Viborg County (DK) - Vestjaelland (DK) - Nordburgenland (A)
livestock density	13	- Rhoen (GER), 5%		- Cambrian Mount. (GB) - Devon Countryside (GB) - Viborg County (DK) - Vestjaelland (DK) - Moura (P) - Castro Verde (P) - Nordburgenland (A) - Osttirol (A) - Schwarzwasser (CH) - Erlach/Seeland (CH) - Bocage-Avenois (F) - Wetterau (GER)
area of grassland	13	- Enkoping (SW), 10%	- Devon Countryside (GB), 5%	- Cambrian Mount. (GB) - Viborg County (DK) - Vestsjaelland (DK) - Offerdal (SW) - Vallakra (SW) - Nordburgenland (A) - Osttirol (A) - Schwarzwasser (CH) - Erlach/Seeland (CH) - Rhoen (GER) - Bocage-Avesnois (F)

[1)] significant at a 5 and 10% level, respectively
(A: Austria, CH: Switzerland, DK: Denmark, ES: Spain, F: France, GB: Great Britain, GER: Germany, GR: Greece, P: Portugal, SW: Sweden)

It should be noted that 9, 13 and 13 observations for the three indicators nitrogen fertiliser, livestock density and grassland area, respectively, are available for analysis in this chapter. Since we are bound by a limited number of observations, the analysis may be seen as an initial attempt to apply meta-analytical techniques to agri-environmental policy evaluation. The statistical procedures applied in this chapter are described in the following section.

7.5 Meta-analytical Methodology

Chapter 5 introduced the concept of effect sizes and mentioned that the empirical application in this chapter makes use of an effect size of the *d*-family, like Hedges' g, Cohen's d or Glass's Δ. An effect size of the *d*-type reflects the difference between the experimental and control group in such a way that it is independent of sample size and unit of measurement. The three examples of the *d*-type effects sizes differ with respect to the method of standardisation.[31] The analysis in this chapter employs Hedges' g as an effect size, which is calculated according to the following equation.[32]

$$g = \frac{M_E - M_C}{S} \tag{7.1}$$

where M_E is the mean of the experimental group, and M_C the mean of the control group. S_p is the pooled sample standard deviation computed as

$$S = \sqrt{v} = \sqrt{\frac{(N_E - 1)V_E + (N_C - 1)V_C}{N_E + N_C - 2}}, \tag{7.2}$$

where V_E and V_C are the variance of the experimental and control groups, and N_E and N_C the experimental and control group sample sizes, respectively.[33]

The effect size of the *d*-type may be interpreted as follows. Generally speaking, a *d*-type effect size gives the difference between an experimental and control group in standard deviation units (Rosenberg et al., 1997). More precisely, the effect size can be interpreted as the z-score of the normal cumulative distribution function, where its respective $\Phi(z)$-value is the proportion of control group scores that is less than the average score of the experimental group (Hedges and Olkin, 1985). For example, an effect size of 0.3 signifies that the score of an average individual in the experimental group exceeds the score of 62% ($\Phi(0.3) = 0.62$) of the individuals of the control group. Cohen's convenient rule of thumb about the interpretation of effect sizes says that 0.2 implies a small effect, 0.5 a medium effect and 0.8 a large effect. Everything above 1.0 is considered to be a very large effect (Rosenberg et al., 1997).

[31] Hedges' g standardises by the pooled (experimental *plus* control group) standard deviation calculated with degrees of freedom (total number of observations minus the number of groups). Cohen's d also standardises by the pooled standard deviation but uses the total number of observations instead of degrees of freedom. Glass's Δ standardises only by the standard deviation of the control group (Rosenthal 1991).

[32] Rosenthal (1991) points out that Hedges' g tends to provide better estimates over the long run of the population standard deviation.

[33] Hedges and Olkin (1985) point out that Hedges' g is negatively biased, especially when sample sizes are small and population effects are large. Because of the small sample argument, we use the adjusted, unbiased g, i.e., g^u, that is obtained by applying $g^u = g \times c(m)$, where $c(m) = 1-(3/(4(m)-1))$ and m are the degrees of freedom computed from the experimental and control group, (N_E+N_C-2). In the analysis c(m) is approximately 0.98, which means that the difference between g and g^u is rather small.

The types of effect size being applied have been defined and explained, and the actual meta-analytical methods will now be described. We divide the procedure into three steps. The first step includes combining effect sizes. The second step investigates potential heterogeneity among the estimated effect sizes. The third step is the moderator analysis.[34]

Step 1: combining effect sizes

It has already been noted that larger samples produce more significant and reliable estimates. It is hence suitable to weight the effect sizes of large sample studies more heavily before combining them. The most appropriate weight is the inverse of the variance of the respective effect sizes, as shown in the following equation.

$$w_i = \frac{1}{v_i}, \qquad (7.3)$$

where w_i is the weight and v_i the variance of the i-th effect size calculated according to Equation (7.2). The combination of the effect sizes obtained from k case studies, g_i, gives the average effect size, $\overline{G_\bullet}$, that is calculated as

$$\overline{G_\bullet} = \frac{\sum_{i=1}^{k} w_i g_i}{\sum_{i=1}^{k} w_i}. \qquad (7.4)$$

For testing the null hypothesis that the average effect size is not significantly different from zero, the Z-statistic will be applied. It is calculated as follows.

$$Z = \frac{\left|\overline{G_\bullet}\right|}{s_\bullet}, \qquad (7.\ 5)$$

where $s_\bullet$ is the average effect size standard error given by

$$s_\bullet = \sqrt{v_\bullet} = \sqrt{\frac{1}{\sum_{i=1}^{k} w_i}}, \qquad (7.6)$$

[34] The description of the statistical procedure is based on Hedges and Olkin (1985) and Shadish and Haddock (1994).

and $v_{\bullet}$ is the average effect size variance. If Z exceeds 1.96, the 95 percent two-tailed critical value of the standard normal distribution, the null hypothesis can be rejected and it can be concluded that the intervention has a significant effect.

Step 2: test on homogeneity of effect sizes

Equation (7.4) assumes that all individual studies share a common effect size. The Q-test tests the null hypothesis that all effect sizes from the individual studies are homogeneous. The Q-test statistic is given in the following equation.

$$Q = \sum_{i=1}^{k} \frac{\left(g_i - \overline{G_{\bullet}}\right)^2}{v_i} \tag{7.7}$$

If the value of Q exceeds the upper tail critical value of the χ^2-square distribution with k-1 degrees of freedom, it has to be assumed that the effect sizes of the individual studies are not homogeneous and that the individual studies do not share a common effect size. Therefore, $\overline{G_{\bullet}}$, as calculated in Equation (7.4), must be interpreted as the *mean* of the observed effect sizes and not as a single effect parameter.

The heterogeneity of the effect sizes of the individual studies shows that factors exist that critically influence the magnitude of the effect sizes. As explained in Chapter 5, these factors are called moderator variables. The analysis of moderator variables is described in the next step.

Step 3: moderator analysis

In the analysis in this chapter, moderator variables should explain the variations of the policy effect in the different case study areas. In other words, they should reflect the reasons why in some case study areas there is a larger behavioural difference between participating and non-participating farmers with regard to a particular indicator than in other case study areas.

Generally speaking, moderator variables can be roughly categorised into three groups. Firstly, there are moderator variables based on the underlying theoretical framework. An example of a moderator variable of the first type is the level of premium paid for participating in an agri-environmental programme. Theoretically, it can be assumed that higher premium levels will induce larger changes in behaviour with respect to specific agricultural practice indicators. Secondly, there is the group of moderator variables that reflect the setting of the particular case study, such as country or time-specific characteristics. Thirdly, there is a group of moderator variables that refer to the methodological characteristics of the primary case studies, which represent the way in which the analysis in the primary study is carried out. Examples are the statistical method used, the functional form chosen or the type of data employed. In the empirical application in this chapter, the individual case studies all apply the same statistical technique, which implies that methodological moderators are not relevant in our case.

The list of potential moderator variables is very long and availability of information is the determining factor for the choice of the moderator variables. The analysis in this chapter investigates the significance of the following moderator variables.

I) Average premium per hectare: Theoretically, higher premiums paid would imply that farmers are more stimulated to change their behaviour with respect to the relevant agricultural practice indicators. Therefore, higher premiums should be related to larger effect sizes.[35]

II) Average farm size: This moderator variable investigates whether effect sizes are influenced by the average farm size in the different case study areas.

III) Absolute level of indicator in 1997: Case study areas that generally have relatively low (nitrogen fertiliser and livestock density) and respectively high (grassland) indicator levels might have lower change rates for participating farmers and hence lower effect sizes.

IV) Intensive versus extensive farming: This moderator variable investigates whether effect sizes in areas of intensive farming differ significantly from those in areas of extensive farming.

V) Arable versus husbandry farming: This moderator variable tests whether effect sizes in areas of arable farming differ significantly from those in areas of husbandry farming.[36]

The basic procedure of performing a moderator analysis is as follows. First, the sample of effect sizes has to be subdivided into two (or more, depending on the number of observations) groups that are associated with particular characteristic

[35] The underlying case studies report average premiums per farm and average farm sizes of participating farms for all case study areas. The moderator variable 'average premium per hectare' is calculated by dividing average premium per farm by average farm size of participating farmers for all relevant case study areas.

[36] In the EU research project, all case study areas are categorised into four groups, each of them describing the characteristics of the agricultural production structure in that area. The four categories are intensive arable farming, extensive arable farming, intensive husbandry farming and extensive husbandry farming. The number of observations available for analysis in this chapter is too small to use all four categories within one moderator analysis. We have therefore simplified the categorisation into 'intensive versus extensive farming' and 'arable versus husbandry farming' and have performed two separate moderator analyses. The moderators 'intensive versus extensive farming' and 'arable versus husbandry farming' are tested only for the indicator 'nitrogen fertiliser'.

reflected by moderator variables. Subsequently, the methods described in Step 1 and 2 have to be applied to the separate groups. In the moderator analysis, two different types of *Q*-tests need to be carried out. First, there is the *Q*-test on heterogeneity *between* the groups (the *Q*-between test) and, secondly, there is the *Q*-test on heterogeneity *within* the groups (the *Q*-within test). The *Q*-between statistic tests the null hypothesis that there is no variation across the mean effect sizes of the groups. In other words, it tests whether a particular moderator variable has a significant influence on the effect size. The *Q*-between statistic is shown in the following equation.

$$Q_{between} = \sum_{i=1}^{p} \frac{\left(\overline{g_{i\bullet}} - \overline{G_{\bullet}}\right)^2}{v_{i\bullet}}, \tag{7.8}$$

where p is the number of groups, $\overline{g_{i\bullet}}$ the average effect size of the ith group, $\overline{G_{\bullet}}$ the overall average effect size (see Equation (7.4)) and $v_{i\bullet}$ the variance of $\overline{g_{i\bullet}}$, calculated according to Equation (7.6), taking into account the observations in that particular group only.

The *Q*-within statistic tests the null hypothesis of homogeneity among the effect sizes within a group. It is presented in the following equation.

$$Q_{within} = \sum_{i=1}^{p} \sum_{j=1}^{m} \frac{\left(g_{ij} - \overline{g_{i\bullet}}\right)^2}{v_{ij}}, \tag{7.9}$$

where m is the number of observations in ith group, g_{ij} the jth effect size in the ith group, and v_{ij} its variance, according to Equation (7.6), taking into account the observations in that particular group only. The sum of the *Q*-between and the *Q*-within statistic results in the overall *Q*-test applied to all observations (see Equation (7.7)).

$$Q = Q_{within} + Q_{between} \tag{7.10}$$

In an ideal case, a selected moderator variable explains the heterogeneity in such a way that most of the heterogeneity occurs between groups. If there is still heterogeneity within groups, the selected moderator variable is unable to explain all variation among the effect sizes. If the number of observations within the group is still large enough, another moderator analysis can be performed within the groups.

7.6 Results

This section presents the results of the meta-analytical methods described in the previous section, applied to the data on the three agri-environmental indicators, nitrogen fertiliser, livestock density and grassland area. First, the results of Step 1, combining significant levels, and Step 2, the test on homogeneity will be presented. Subsequently, the results of the moderator analysis are shown.

Results of steps 1 and 2:

The outcomes of step 1 and step 2 are reported in Table 7.3.

Table 7.3: Results of steps 2 and 3

	k	*N* (N_E, N_C)	*Hedges' g*	*SE*	*Z*	*Q*	$P_{(Q)}$
N-fertiliser	9	349 (242,107)	-1.57	0.15	10.24*	52.24	0.00
Livestock	13	630 (445,185)	-0.82	0.11	7.35*	161.81	0.00
Grassland	13	569 (428,141)	-0.83	0.12	6.80*	169.84	0.00

k: number of case study areas, *N*: number of individual farmers, N_E: number of individual farmers in experimental group (participants), N_C: number of individual farmers in control group (non-participants), *SE*: standard error of Hedges' g.

Table 7.3 shows that the combined effect sizes of all three indicators are significantly different from zero. Although most of the original case studies show insignificant results, the combined effect sizes show that there is an overall difference between the change rates for participating and non-participating farmers.

The effect sizes of the indicators 'nitrogen fertiliser' and 'livestock density' have the expected negative sign. However, the sign of the effect size of the indicator 'grassland' is unexpectedly negative. This result is paradoxical because the policy is meant to increase the area of grassland. The fact that the confidence interval does not include zero makes this result even more contradictory.

The indicator 'nitrogen fertiliser' has the highest average effect size, -1.57, which implies that 94% (Φ (1.57) = 0.94) of the change rates of non-participating farmers were lower than the average change rate of participating farmers. According to Cohen's rule of thumb (see Section 7.5), this reflects a very large effect of the policy intervention regarding the use of fertiliser. It should be noted that effect sizes cannot be used to infer the difference in the actual size of the change rates of participating and non-participating farmers, but only the percentage value by which the change rates of non-participants are lower than the average change rate of participants.

The effect size for the indicator ‘livestock density’ is -0.82, which implies that 79% of the change rates of non-participating farmers were lower than the average change rate of participating farmers. According to Cohen’s rule of thumb, this effect size also shows a large effect of the policy intervention.

The *Q*-test on homogeneity signifies, with a very high significance level for all three indictors, that the effect sizes of the individual case study areas are heterogeneous. This means that the case study areas do not share a common effect size, but that the calculated effect size is only the mean of the effect sizes in the individual case study areas.

Results of step 3:

Since the calculated effect sizes do not pass the *Q*-test of homogeneity, moderator analyses as described in step 3 in the previous section are carried out. The moderator variables ‘average premium per hectare’, ‘average farm size of participating farmers’ and ‘average absolute value in 1997 (of the indicator)’ are tested. Finally, the moderator variables ‘intensive versus extensive farming’ and ‘arable versus husbandry farming’ are considered, but only for the indicator ‘nitrogen fertiliser’.

I) Average premium per hectare:

The results of the moderator analysis 'average premium per hectare' are shown in Table 7.4.

Table 7.4: Results of moderator analysis ‘average premium per hectare’.

	N-FERTILISER			LIVESTOCK DENSITY			GRASSLAND		
2 groups	*Hedges'g*	*Q*	$P_{(Q)}$	*Hedges'g*	*Q*	$P_{(Q)}$	*Hedges'g*	*Q*	$P_{(Q)}$
< 40 ECU	-1.31	22.17	0.00	-0.51	106.17	0.00	-0.81	66.06	0.00
> 40 ECU	-1.83	27.19	0.00	-1.78	31.83	0.00	-0.85	103.76	0.00
Q between		2.88	0.09		23.81	0.00		0.02	0.88
Q within		49.36	0.00		138	0.00		169.82	0.00
3 groups									
< 30 ECU	-0.80	8.24	0.02	-0.41	38.47	0.00	-0.64	63.24	0.00
> 30 ECU	-2.54	0.45	0.8	-0.60	69.15	0.00	-1.46	9.229	0.03
> 100 ECU	-1.23	18.13	0.00	-1.92	24.35	0.00	-0.26	81.45	0.00
Q between		25.42	0.00		29.84	0.00		15.93	0.00
Q within		26.82	0.00		131.97	0.00		153.91	0.00

For the moderator variable ‘average premium per hectare’ two types of analysis are carried out. In the first analysis, the effect sizes are divided into two groups. The groups comprise all case study areas where the average premium is lower/higher than 40 ECU per hectare. The results of the first analysis are shown in the upper part of Table 7.4. For the indicators ‘nitrogen fertiliser’ and ‘livestock density’, the results are as expected: higher average premiums per hectare result in larger effect sizes. The

Q-between test is highly significant for 'livestock density', and significant at a 10% level for 'nitrogen fertiliser'. This implies that the effect sizes of the two groups are significantly different from each other. However, the *Q*-within statistics still indicate heterogeneity among the effect sizes in the two groups. For the indicator 'grassland', the effect sizes of the two groups are not significantly different from each other as indicated by the *Q*-between test, which has a *p*-value of 0.88.

Since the *Q*-within tests in the 2-groups analyses still indicate heterogeneity among effect sizes, a second analysis is carried out. In the second analysis, it is tested whether a division into 3 groups improves the *Q*-within tests. The results of the division into groups as well as the results of the second analysis are shown in the lower part of Table 7.4. The results show that only for the indicator 'livestock density' do increasing premiums per hectare result in higher effect sizes. The *Q*-between test still rejects the null hypothesis of homogeneity among the average effect sizes of the three different groups. The *Q*-within statistic slightly decreased, but there is still heterogeneity among the effect sizes within the groups. For the indicator 'nitrogen fertiliser', the second group shows the largest effect size, and it is also one of the few cases where the *Q*-within test indicates homogeneity. For the indicator 'grassland', the *Q*-between test now signifies heterogeneity among the average effect sizes between groups. However, the unexpected negative signs persist in all groups.

To summarise, in the 3-groups analysis, the *Q*-between tests still indicate heterogeneity, which means that the moderator 'average premium per hectare' has a significant influence on the magnitude of the effect sizes. In addition to between-group heterogeneity, the *Q*-within tests should indicate homogeneity. This does not occur in the moderator analysis performed here. Unfortunately, the number of observations is too small for a more differentiated analysis including multiple moderator variables.

II) Average farm size of participating farmers

The results of the moderator analysis 'average farm size' are presented in the Table 7.5.

Table7.5: Results of moderator analysis 'average farm size'

	N-FERTILISER			LIVESTOCK DENSITY			GRASSLAND		
2 groups	*Hedges'g*	*Q*	$P_{(Q)}$	*Hedges'g*	*Q*	$P_{(Q)}$	*Hedges'g*	*Q*	$P_{(Q)}$
< 80 ha	-1.54	21.85	0.00	-0.92	100.85	0.00	-0.87	103.71	0.00
> 80 ha	-1.59	30.36	0.00	-0.72	60.12	0.00	-0.81	66.07	0.00
Q between		0.03	0.87		0.84	0.36		0.063	0.80
Q within		52.21	0.00		160.97	0.00		169.78	
3 groups									
< 40 ha	-1.23	18.13	0.00	-1.92	24.35	0.00	-0.26	81.45	0.00
> 40 ha	-1.55	4.66	0.1	-0.16	45.89	0.00	-1.20	46.65	0.00
> 100 ha	-1.84	26.97	0.00	-0.89	54.47	0.00	-0.86	32.73	0.00
Q between		2.471	0.29		37.10	0.00		9.01	0.01
Q within		49.77	0.00		124.71	0.00		160.84	0.00

As in the previous moderator analysis, we performed two types of moderator analysis, one with two groups and another with three groups. In the first analysis, the groups contain all case study areas where the average farm size of participating farmers is lower/higher than 80 ha. The results are shown in the upper part of Table 7.5. The *Q*-between tests of all three indicators signify homogeneity between the effect sizes of the two groups. This means that this analysis does not support the assumption that the moderator variable 'average farm size of participating farmers' has a significant influence on the magnitude of the effect size.

The results of the division into groups and the results of the second analysis are presented in the lower part of Table 7.5. For the indicator 'nitrogen fertiliser', the *Q*-between test still shows homogeneity of average effect sizes of the three groups, indicating that even in a more differentiated analysis, the average farm size of participating farmers does not seem to influence the magnitude of the effect size. For the other two indicators, the *Q*-between test shows heterogeneity between the average effect sizes of the three different groups. However, the *Q*-within test still indicates heterogeneity among the effect sizes inside the groups in all cases. As in the previous moderator analysis, the limited number of observations precludes a more differentiated analysis.

III) Average absolute value 1997

In the third moderator analysis, we divide the effect sizes from the different case study areas into two groups. For the indicator 'nitrogen fertiliser', the groups contain the case study areas where the average absolute value in 1997 was lower/higher than 40 kg/ha. For the indicator 'livestock density', the groups comprise all case study areas with, on average, less/more than 1.5 livestock units per hectare in 1997. For the indicator 'grassland', the two groups are characterised by less/more than 50% grassland area per UAA in 1997. The results of the moderator analysis of 'average absolute value in 1997' are shown in Table 7.6.

Table 7.6: Results of moderator analysis of 'absolute value in 1997'

N-FERTLISER				LIVESTOCK DENSITY				GRASSLAND			
	Hed.g	*Q*	$P_{(Q)}$		*Hed. g*	*Q*	$P_{(Q)}$		*Hed.g*	*Q*	$P_{(Q)}$
<40 kg/ha	-1.11	22.85	0.00	<1.5 LU/ha	-0.56	81.31	0.00	<50%	-0.73	75.73	0.00
>40 kg/ha	-1.93	22.28	0.00	>1.5 LU/ha	-1.10	74.64	0.00	>50%	-0.92	93.48	0.00
Q betw.		7.12	0.01			5.86	0.02			0.63	0.43
Q with.		45.12	0.00			155.95	0.00			169.21	0.00

The *Q*-between test signifies heterogeneity between the average effect sizes of the two different groups for the indicators 'nitrogen fertiliser' and 'livestock density'.

This implies that the average absolute value in 1997 seems to have a significant influence on the magnitude of the average effect size. As expected, the case study areas with higher absolute levels of the indicators have higher average effects. This means that in areas with higher absolute values of the indicator in 1997, a higher percentage of the change rates of non-participating farmers are lower than the average change rate of participating farmers. For the indicator 'grassland', the *Q*-between test reports homogeneity between the average effect sizes for the two groups. The *Q*-within tests show heterogeneity among the effect sizes for all cases.

IV and V) Intensive versus extensive farming, husbandry versus arable farming
The last two moderator analyses are applied to the 'nitrogen fertiliser' indicator only. The results are given in Table 7.7.

Table 7.7: Results of moderator analysis 'intensive versus extensive' and 'arable versus husbandry'

N - F E R T I L I S E R							
	Hedges' g	*Q*	$P_{(Q)}$		*Hedges' g*	*Q*	$P_{(Q)}$
Intensive	-1.49	11.90	0.01	Arable	-1.48	43.35	0.00
Extensive	-1.67	40.00	0.00	Husbandry	-1.87	7.68	0.01
Q between		0.34	0.56	Q between		1.21	0.27
Q within		51.90	0.00	Q within		51.03	0.00

Table 7.7 shows that the effect size for intensive farming is slightly lower than those for extensive farming, and that the effect size for arable farming is lower than those for husbandry farming. However, the *Q*-between test signifies that the null hypothesis of between-group homogeneity cannot be rejected in both cases. This means that the production structure in the case study areas, i.e., whether it is characterised by intensive/extensive or arable/husbandry farming, does not have an influence on the magnitude of the effect size. As in most of the previous moderator analyses, the *Q*-within tests still indicate heterogeneity among the effect sizes in the two groups.

7.7 Conclusions and Discussion

The analysis in this chapter has applied meta-analytical methods to agri-environmental policy evaluation in the European Union. Because of limited data availability, this study has to be regarded as exploratory. Nevertheless, some general conclusions can be drawn on the basis of the analysis. First, the fact that meta-analysis artificially lowers the variance of the sample observations shows up in the results of step 1, combining effect sizes. This result implies that, although most of the original case studies show insignificant differences between the change rates of participating and non-participating farmers, the combined effect sizes demonstrate that there is an overall difference between the change rates. In other words, there is an indication that the agri-environmental policy intervention does indeed have a positive effect on the behaviour of participating farmers with respect to the chosen indicators.

On the basis of the moderator analyses, it can be concluded that the variables 'average premium per hectare' and 'average absolute value in 1997' have a significant effect on the magnitude of the effect sizes. The moderator variable 'average premium per hectare' indicates that the effect sizes for the indicator 'livestock density' do increase with increasing payment levels. However, for the indicator 'nitrogen fertiliser', the theoretical assumption that increasing payment levels result in higher effect size estimates is not unambiguously confirmed by the data analysed. This result may lead to the conclusion that farmers, once they are advised to reduce nitrogen fertilisation, take into account the cost savings attached to a reduction in fertiliser use. They may realise that a reduction (optimisation) of fertiliser use is beneficial for the financial situation of the farm, even without compensation payments.

The moderator variable 'average absolute value in 1997' indicates higher effect sizes for more intensive farms, i.e., farms with a higher livestock density and greater use of nitrogen fertiliser in 1997. The analyses of the moderator variables 'average farm size', 'intensive versus extensive farming' and 'arable versus husbandry farming' do not show any significant results on the basis of the data analysed.

In general, the effect sizes of the indicator 'nitrogen fertiliser' show the highest values. This may be explained by the fact that reduction of nitrogen fertiliser is easier to organise and less dependent on other conditions than reduction of livestock density or an increase in grassland area. The number of livestock kept by a farmer is rather susceptible to the current prices of meat and livestock, which might outweigh the payments from agri-environmental programmes. The effect sizes of the indicator share of grassland area per UAA unexpectedly exhibit negative signs. This paradoxical result may be due to the fact that the indicator 'grassland area' is a very broad measure and is subject to multiple decision-making processes including ones outside the agricultural sector such as urban and landscape planning.

A prevailing problem throughout all moderator analyses is that the *Q*-within tests signify heterogeneity of the effect sizes within the different groups. The occurrence of this problem underlines the diversity of the European landscape and the differences in the structure of the agricultural sector, which are often emphasised by researchers trying to evaluate European agri-environmental policy. The methodology of meta-analysis may be able to shed more light on this diversity, if a sufficiently large number of observations (i.e., underlying case studies) were available. A sufficiently large number of observations would allow the application of more advanced methods of meta-analysis that take into account multiple moderator variables, such as multifactor analysis or meta-regression analysis.

The EU research project that provided the case studies for the analysis supports the introduction of monitoring programmes in which the behaviour of participants and non-participants can be compared. The use of such quasi-experimental impact assessments would improve the feasibility of comparing policy outcomes with policy objectives. Quasi-experimental case study results would also increase the amount of potential input data for meta-analytical study.

CHAPTER 8

APPLICATION C:

THE EFFECTS OF AGRICULTURAL INCOME ON LAND PRICES

8.1 Introduction

The capitalisation of agricultural income, price support and government payments into agricultural land and other asset values has received considerable attention in the economic literature. It has been pointed out in Chapter 3 that a specific feature of land as a factor of production is the fact that it is the input with the least elastic supply. According to standard economic theory, this implies that its value increases most as a result of product price increases, such as those caused by agricultural price support. Several policy questions emerge when considering the extent to which agricultural income is capitalised into land values. One of the main objectives of agricultural policy is to stabilise and support the income of farmers and the rural community. However, if agricultural policy results in an increase in land prices, part of the agricultural support might flow out of the agricultural sector if farmers are not owner operators but tenant farmers. In fact, farmers who have to rent land might even be worse off, because increasing land values imply increasing land rents and hence higher costs for tenant farmers. Another policy issue, which was introduced in Chapter 2, is the role of land prices in land use decision-making. Inflated agricultural land values increase farmers' capital costs, implying that high production values (attained through the use of intensive production methods) are needed in order to earn back these costs. A price reduction for land, possibly resulting from a change in agricultural policy, might hence induce a trend towards less intensive production patterns. This intensity reduction may also have positive effects on environmental quality in rural areas, and induce alternative, more environmentally friendly land uses (OECD, 1998c).

The literature describes numerous studies that report estimates of the impact of changes in agricultural price support payments on land prices. The empirical results of these studies vary considerably, depending on such factors as their definition of the agricultural income indicator, the geographical location, the time period covered and the econometric techniques applied. The analysis in this chapter compares these empirical results using meta-regression analysis, which was introduced in Chapter 5.

A major problem encountered when trying to compare estimates from the various studies is their lack of consistency in terms of the precise definition of the agricultural income indicator. Whereas some of the studies use net farm income or some type of adapted net farm income as an indicator, others use market revenues, government payments or total farm cash receipts. Obviously, the estimates reflecting the effect of the different types of agricultural income indicators on agricultural land prices are not directly comparable. The analysis in this chapter offers a method for making these estimates comparable so that they can be used as input for the meta-regression analysis.

Although the different types of agricultural income indicators create a 'comparability' problem, they can provide insight into the impact that the various sources of agricultural income may have on land prices. For instance, studies that employ government payments, i.e., direct agricultural income support, may produce different estimates than studies that employ pure market revenues, where only the price support component is considered. Comparing these results in a meta-analytical framework may shed some light on the effect a policy shift from price to direct income support (as is currently being contemplated in many industrialised countries) might have on agricultural land prices.

In Chapter 5, Section 5.4, a major methodological problem in meta-analysis was described: the potential dependency between observations in the meta-sample. The dependency may not only occur due to multiple sampling from the same study, but also because different studies use the same data sources for their statistical analyses. In this chapter, we suggest a method for testing and correcting for within and between-study dependence by using spatial statistical tools that were originally developed to account for multidimensional autocorrelation between adjoining geographical areas.

The chapter is organised as follows. Section 8.2 highlights important aspects of the agricultural land price literature that need to be incorporated into the meta-regression analysis. Section 8.3 describes the construction and characteristics of the meta-data set and demonstrates the method for making the estimates from the different agricultural income indicators comparable. In Section 8.4, we extend the introductory description of meta-regression analysis presented in Chapter 5 and provide, additionally, a methodology for accounting for dependency among the meta-observations. Section 8.5 contains the results and Section 8.6 closes with a discussion and conclusions.

8.2 Empirical Agricultural Land Prices Literature

Floyd (1965) and Gardner (1987) provide a theoretical microeconomic framework for analysing the effects of various forms of agricultural support policies on land prices. They investigate the effects of agricultural support programmes under different types of output control in a single-output, two-input mode. Land price elasticities, derived under a number of assumptions for key parameters, vary widely depending on differing assumptions about output control.[37] Along with this theoretical research, there is a series of empirical studies of farmland rents and values.[38] The discussion on land rents and values in Chapter 3 (Subsection 3.2.2) has established that the literature on agricultural land price determination can be divided into two broad categories (Shi et al., 1997). To summarise, on the one hand, there is the category of studies using income from agricultural production as the major determinant of land rent and prices. The theoretical framework underlying most of these studies is the asset pricing or capitalisation model, which has been introduced in mathematical terms in Chapter 3. In short, this model implies that the value of an asset is equal to the discounted value of all future expected earnings. On the other hand, there is the category of studies employing mainly non-farm factors to explain the variation in agricultural land prices. These studies are based on the hedonic pricing model that is used to distinguish the effects of quality differences and location. It has to be noted that the two categories do not have to be considered strictly separated. Urban economic models describe the value of farmland as the discounted value of future earnings from a combined stream of agricultural and non-agricultural uses (e.g., Capozza and Helsley, 1989; Hardie et al., 2001). These models are asset pricing models that incorporate hedonic variables representing differences in quality and location.

The main reason for the increasing interest in the determinants of agricultural land prices, especially in the US, was the explosive increase in farmland prices in the 1970s followed by an equally rapid decrease in the 1980s. Economists have suggested a variety of reasons for this cyclic pattern of farmland prices. These include changes in agricultural returns (Alston, 1986; Burt, 1986; Phipps, 1984), inflation and real interest rates (Just and Miranowski, 1993; Gertel, 1990; Feldstein, 1980), capital gains (Castle and Hoch, 1982; Melichar, 1979) and debt acquisition (Shalit and Schmitz, 1982; Reinsel and Reinsel, 1979).

The above discussion shows that there is considerable consensus about theoretical and modelling aspects of land price determination. However, as pointed out by Robison and Koenig (1992), the most striking aspect of the asset pricing and hedonic pricing literature is the lack of consensus regarding the data that adequately represent the rent and the way in which expectations should be modelled. Different types of income indicators approximate land rent. A popular approximation of land rent, which is used in many studies, is net farm income. Net farm income is generally

[37] The model predicts that price support with output controlled by a non-tradable quota results in the highest increase in land values followed by a price support regime without output control. Price support with acreage control where farmers are compensated for the land taken out of production also results in increasing land values. Decreasing land values can be expected with output controlled by a tradable quota.

[38] Under conditions of perfect competition, land price and value are considered equal. Although under the actual conditions of the land market, price and value may differ (Reynolds and Timmons, 1969), the terms 'land value' and 'land price' are used interchangeably in this chapter.

defined as the residual income from agriculture after deducting costs for capital, land and hired labour. However, some economists have mentioned that net farm income may be inappropriate for measuring returns to land. They recommend employing pure returns to land, such as rental rates or net rent, instead (Featherstone and Baker, 1987; Burt, 1986; Castle and Hoch, 1982; Melichar, 1979). The net rent data series that is used in a number of studies is, in fact, an adapted version of the net farm income series. For example, Melichar (1979) defines the net rent data series as net farm income minus imputed returns to operator labour, management and household assets, plus interest payments on farm durable assets including rent, plus net rent and government payments to non-operator landlords. Unfortunately, net rent data are most often available only for the U.S. Studies dealing with areas outside the U.S. are hence forced to use other agricultural income indicators to operationalise the rent concept. For instance, Canadian studies often employ cash rent, farm income or gross farm income (Gunjal et al., 1996). Another group of studies resorts to the agricultural production value or market revenue, defined as the physical yield times the average price.

In addition to the use of the aforementioned income indicators, some studies explicitly focus on determining the land price elasticity of direct government payments. Unlike price support measures that influence farmers' income solely through the sales of agricultural products, direct government payments are transfers to farmers that are supposed to be decoupled from agricultural production. A distinction between the estimates based on the former type of income indicators and those focusing on government payments may indicate the different influences of a mixed system of price and income support, which is incorporated into the former income indicators, and of pure income support on land prices. Obviously, the different types of income indicators are not independent of each other, since all of them are components of the farm's financial statement concept. Direct comparison of the estimates that represent the effects of the different types of income indicators in the various studies would hence be of questionable value. In Section 8.3, we provide a method for making the estimates suitable for comparison.

The capitalisation model, which has explicitly been described in Chapter 3 (Equation 3.1), says that the value of land is determined by *expectations* of the future returns to land. Chapter 3 has also pointed out that the expectation formation mechanism is very important for characterising market behaviour. The formulation of expectation is another important source of variation among the empirical studies in the literature. Ways in which the expectation aspect of farm revenues is accounted for include the weighted average of income over a number of previous years (e.g., Gunjal et al., 1996; Gertel, 1990), the so-called Fisher lag (e.g., Weisensel et al., 1988; Traill, 1979) and the inclusion of an income variable lagged one or more years (e.g., Featherstone and Baker, 1988; Burt, 1986).

Apart from the apparent differences in the type of rent approximation and the formulation of expectations, there are many more potential sources of structural variation among studies. Variations with respect to study characteristics include differences in the location of the study area, the ways in which and the extent to which the agricultural characteristics of the area are taken into account and divergence in the time periods considered. Another important source of variation is related to the nature of the data employed. The use of time series data is very popular in agricultural land price studies. There are also, however, studies that use cross section data or a time series of cross section data. Kuh (1959) shows that elasticities evaluated with cross section data are generally larger than those for time series data, since they tend to estimate long run effects. In general, the theory suggests that long run elasticities are greater than short run elasticities. Furthermore, the level of aggregation has been hypothesised to have an effect on the magnitude of the estimates as well. Burt (1986) points out that difficulties, such as heterogeneity of land quality, the influence of non-agricultural values and inaccurate estimates of rents and land values, are aggravated by using highly aggregated data. The estimated elasticities derived from aggregated data may be biased downwards. Other factors responsible for variation among studies are related to the specification of the model and the estimation technique used. Table 8.2 in the following section shows the different categories for classifying the variations in the studies used for the meta-regression analysis in this chapter.

8.3 Sampling Frame and Data

Every meta-analysis begins with an intensive literature retrieval process. In order to avoid selection bias we have compiled a gross list of studies using references in available publications and extensively searching online databases.[39] We have limited the initial retrieval to studies containing a *quantitative* assessment of agricultural land prices or values that include indicators for agricultural income, rent or government payments in the set of explanatory variables. The initial sample contains over 50 studies. Unfortunately, many studies in the first set of studies exhibit one or both of two major complications that prohibit the comparison of the estimated coefficients. First, some studies report estimates of absolute changes in land values, which means that the coefficients are not dimension-free. For studies that provide enough information to calculate an elasticity, the first complication can be overcome. However, a considerable number of studies do not provide enough information in order to calculate an elasticity. Secondly, a number of studies, in particular those dealing with European countries, use different units of measurements for the agricultural income variables (e.g., agricultural income per worker, national or

[39] We searched EconLit (http://www.econlit.org), Agris (http://www.silverplatter.com/catalog/aris.htm) and AgEcon Search (http://agecon.lib.umn.edu), which contains the (unpublished) working papers of several agricultural economics departments and institutes. We used the keywords ‘farm’ and ‘agriculture’ in combination with ‘land prices’, ‘land values’, ‘land markets’, ‘land policy’ and ‘policy’.

regional income from agriculture) and the land value variables (e.g., land value per hectare). In this case, the estimated coefficients are also not dimension-free, making straightforward comparison of the estimates impossible. Therefore, in a second selection procedure, we sampled only those studies that a) directly report an elasticity (by means of a double logarithmic model specification), b) provide enough information for computing an elastictiy and c) employ a per-acre or per-hectare unit of measurement for both variables under consideration. The second selection procedure yielded 19 studies, from which we sampled 228 observations. Among the 228 observation, we identified 10 outliers.[40] The final data contains 218 observations. The studies are listed in Table 8.1.

Table 8.1 shows that the first study was performed in the mid-1960s. The latest study is from 2001. Most studies are concerned with the US and a considerably lower number with Canada and Europe. The underlying data cover a period from the 1940s to the 90s, and are time series, spatial cross section or pooled data. Ordinary least squares is the dominant estimation technique, although many studies use either a more sophisticated single-equation estimator or a systems-estimator. Most studies use a double-log specification and employ a lag structure to model future expectations.

The meta-observations obtained from the different studies, vary considerably, ranging from one observation from three studies to a maximum of 68 from one study, namely Runge and Halbach (1990).[41] The discussion of the methodological problems inherent in meta-analysis in Chapter 5 pointed out that multiple sampling of observations from one study may violate the standard independent distribution assumption of regression analysis. Furthermore, the diverging numbers of observations in the original studies, as reported in Table 8.1, offer an initial indication of the efficiency of the estimated elasticities. They vary widely, between 15 and 2236, and may violate the identical distribution assumption typical of regression analysis. We will deal with these methodological problems below.

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[40] The way we have identified the outliers is described in the following section.

[41] Elasticity estimates are straightforwardly obtained. For example, Runge and Halbach (1990) estimate distinct effects on land values for domestic market returns, foreign market returns and direct government payments in a model pertaining to eight US states and three different time periods. We sample 3 observations for different types of returns, for eight different states and three different time-periods, resulting in 72 meta-observations (68 after excluding outliers). A similar sampling framework applies for other studies, including studies with a multiple lag structure. For example, Gertel (1990) and Burt (1986) include agricultural income with and without a temporal lag, implying that we sample two meta-observations for the different specifications.

Table 8.1: Overview of studies included in the meta-sample

Study	Usable estimates[1]	Country	Time period	Elasticity[2]				Revenue indicator	Lag structure	Type of data	Functional form[3]	Estimator	# of Obs.
				Min	Max	Mean							
						Orig.	Transf.						
Tweeten and Martin (1966)	1	US	1923-63	0.086	0.086	0.086	0.086	NFI	lagrent	time series	others	OLS	41
Van Vuuren (1968)	2	US	1952-65	0.253	0.254	0.254	0.209	RL	none	pooled	double-log	SYSEQUA	140
Reynolds and Timmons (1969)	20	US	1933-65	0.087	0.951	0.458	0.625	various	average	various	others	OLS	33-48[4]
Morris (1978)	1	US	1969	0.585	0.585	0.585	0.171	MR	none	cross sect	others	OLS	2952
Klinefelter (1973)	6	US	1951-70	-0.013	0.043	0.008	-0.019	various	various	time series	various	OLS	20
Traill (1979)	2	EUR	1946-78	1.160	1.190	1.175	1.175	NFI	average	time series	others	NONOLS	33
Shalit and Schmitz (1982)	3	US	1950-78	0.034	0.051	0.041	0.131	RL	lagrent	time series	double-log	SYSEQUA	29
Pope (1985)	2	US	1981	0.224	0.262	0.243	0.558	RL	none	cross sect	others	OLS	592
Burt (1986)	16	US	1960-83	-0.144	0.246	0.069	0.166	RL	various	time series	double-log	NONOLS	12-24[4]
Weisensel et al. (1988)	4	CA	1950-85	-0.342	0.284	0.088	0.055	MR	average	time series	double-log	NONOLS	29-32[4]
Gertel (1990)	22	US	1942-87	-0.013	1.789	0.196	0.187	RL	various	various	double-log	various	28-60[4]
Runge and Halbach (1990)	68	US	1949-85	-0.313	1.184	0.305	0.767	various	none	time series	double-log	OLS	15-37[4]
Folland and Hough (1991)	6	US	1978	0.355	0.427	0.386	0.084	MR	none	cross sect	double-log	various	494
Veeman et al. (1993)	15	CA	1961-87	0.260	1.520	0.819	0.177	MR+GP	average	time series	double-log	NONOLS	27
Cavailhes and Degoud (1995)	6	EUR	1961-93	0.270	1.200	0.702	0.702	NFI	various	time series	double-log	OLS	33
Barnard et al. (1997)	6	US	1994-96	0.120	0.690	0.265	1.551	GP	none	pooled	double-log	OLS	NA
Shi et al. (1997)	1	US	1950-92	0.013	0.013	0.013	0.013	NFI	none	pooled	others	NONOLS	2236
Weersink et al. (1999)	32	CA	1949-93	0.002	1.313	0.309	0.761	various	lagrent	time series	others	SYSEQUA	45
Hardie et al. (2001)	5	US	1982-92	0.405	0.605	0.474	0.114	MR	none	pooled	others	SYSEQUA	690
TOTAL	218												

[1] After excluding outliers.
[2] 'Min' and 'Max' show the minimum and maximum values of the original elasticities; 'Transf.' Indicates the transformed value of the elasticity (the transformation process is described later in the text.
[3] Indicates the way in which the elasticity is calculated: 'double-log' means that elasticity is directly estimated by the model in the underlying paper, 'others' means that it is calculated based on absolute changes and mean values of relevant variables.
[4] Different models in the respective papers are based on varying numbers of observations.

Legend: CA is Canada, EUR Europe, MR market revenue, GP government payments, NFI net farm income, RL returns to land, NONOLS estimators different from OLS (for instance, (E)GLS, maximum likelihood or GMM), SYSEQUA system of equations, and NA not available.

In the preceding section, we have pointed out the complicating heterogeneity among studies in terms of the income indicator used in the different studies. We distinguish between eight different farm income indicators:

a) net farm income
b) government payments
c) market revenues
d) total farm cash receipts (market revenues plus government payments)
e) market revenues from domestic markets
f) market revenues from foreign markets
g) net farm income excluding government payments
h) returns to land (net farm income corrected according to Melichar (1979))

The eight income indicators are components of the farm financial statement concept. Roughly speaking, net farm income, Y, is identified as market revenues, MR, plus government payments, GP, minus costs for variable inputs and production factors, C.[42] This is an identity: $Y \equiv MR + GP - C$. A change in net farm income is not the same as a change in market revenues or government payments. This implies that the elasticities derived from these data series are not equivalent. Rather, changes in market revenues and government payments result in changes in net farm income. We therefore need to estimate the relationship between changes in market revenues and government payments on net farm income and convert all elasticities to elasticities with respect to net farm income before comparing them. We will explain the conversion on the basis of market revenues.

Land price elasticities with respect to market revenue and net farm income are defined as $\eta_{MR} = (\partial p_l / \partial MR) \times (MR / p_l)$ and $\eta_Y = (\partial p_l / \partial Y) \times (Y / p_l)$, respectively, where p_l indicating the price of land. In terms of the common demoninator, Y, the former elasticity reads as:

$$\eta_{MR} = \frac{\partial lp}{\partial MR} \cdot \frac{MR}{lp} = \frac{\partial lp}{\partial Y} \cdot \frac{\partial Y}{\partial MR} \cdot \frac{MR}{lp} . \tag{8.1}$$

The above identity implies $\partial Y / \partial MR = 1$, so by multiplying the right hand side of (8.1) with $(Y / p_l) \times (p_l / Y)$ and rearranging, we obtain:

$$\eta_{MR} = \frac{\partial lp}{\partial Y} \cdot \frac{MR}{lp} \cdot \frac{Y}{lp} \cdot \frac{lp}{Y} = \frac{MR}{Y} \eta_Y \qquad \text{or} \qquad \eta_Y = \frac{Y}{MR} \eta_{MR} , \tag{8.2}$$

[42] Net farm income is the remuneration for farmers (and their families) for unpaid labour, management skills and equity capital (for instance, land and machinery). The precise definition of net farm income differs between countries and changes over time. For an overview of definitions of net farm income, see, e.g., Hill (1996).

where *Y*/*MR* is the relevant correction factor. The correction factors for the other income indicators are derived accordingly.

In other words, the land price elasticities with respect to market revenues need to be multiplied by the ratio of net farm income to market revenues in order to be comparable with the elasticities with respect to net farm income. Correction factors for other types of income indicators are calculated accordingly.[43]

Figure 8.1 shows the distribution of the 228 corrected elasticities ordered by size.

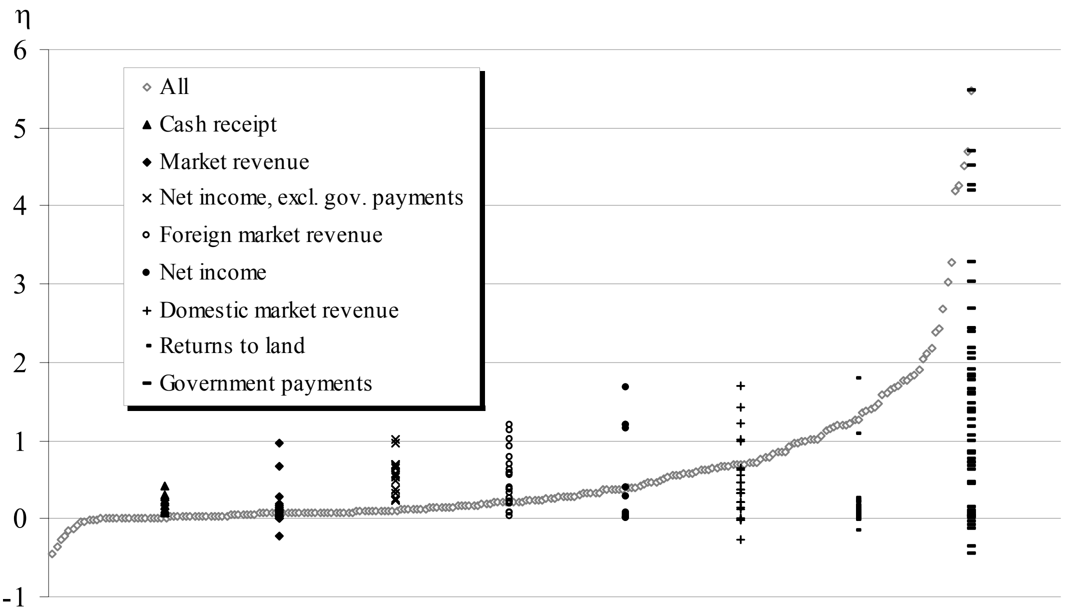

Figure 8.1: Corrected elasticities ordered by magnitude for the total sample and ordered according to increasing range for each income indicator.

[43] Collecting the data for calculating the correction factors was a labour-intensive process. Data series for all identified income indicators, for the different countries, states or provinces, and for the different time periods for which the estimates in the underlying studies are based had to be retrieved in order to calculate the appropriate correction factor for each estimate. We retrieved the necessary data for the US from the USDA (Economic Research Service) website (http://www.ers.usda.gov/Data), which provides farm balance sheets for all states and time-periods. For Canada, we used Statistics Canada-Catalogue No.21-603. The 'European' estimates are all based on net farm income and do hence not require conversion. The correction factors are calculated for the average values for the time periods on which the estimates are based. Data concerning domestic and foreign market revenues for the sample period 1949-1985, considered in Runge and Halbach (1990), are not available. We therefore use the period 1996-2000, considering it the best possible approximation. In order to find out whether these approximations have a significant effect on the overall results, we also made an analysis excluding the observations for domestic and foreign market revenue. They do not substantially alter the overall results.

Figure 8.1 shows that the minimum elasticity is -0.45 and the maximum +5.47. The average is +0.55, revealing that capitalisation of income in land values is inelastic. The distribution has a standard deviation of +0.87. Figure 8.1 also presents the distribution of the corrected elasticities according to the original income indicator, in increasing range. The estimated corrected elasticties using cash receipts as the income indicator are positive and inelastic, with small variance. The elasticties for net farm income, market revenues and returns to land show considerably more variation, but the majority are smaller than unity. The widest spread appears for government payments, showing approximately as many inelastic as elastic values. It can be recognised that the elasticities for government payments include a number of outliers. We will come back to the issue of the outliers in the next section.

Table 8.2 gives an overview of the characteristics of the meta-data to be used in the meta-regression analysis. As mentioned above, we distinguish between eight different *income indicators*. Table 8.2 shows that approximately 50% of the observations concern returns to land, government payments and market revenue. There are remarkably few estimates using net farm income directly. The dominant *modelling approach* is the pure asset pricing model. Slightly more than 10 percent of the estimates are derived in a hedonic pricing framework. *Expectations* are not explicitly modelled in approximately 50 percent of the estimates, whereas the remaining estimates are almost proportionally inferred using lagged income or a (weighted) average of lagged income in prior years.

Table 8.2 shows, furthermore, that approximately 10 percent of the sample concerns the long run *type of elasticities* and approximately 60 percent concerns directly obtained elasticities using the double logarithmic model specification. In order to account for differences between the specifications used in the primary studies, we indicate the inclusion of lagged land price and capital gains. According to the theory, lagged land prices are supposed to incorporate the expectations of farmers in the past. It can hence be assumed that elasticities estimated on the basis of a model including lagged land prices would be biased downwards.

It is not feasible to specify the *type of product* considered in the underlying studies for roughly 30 percent of the sample, since the primary studies use aggregated agricultural output. More than half of the estimates refer to the production of grain and wheat. As for *spatio-temporal coverage*, around 70 percent of the estimates cover the U.S., of which one quarter deal with the cornbelt. The other estimates nearly all deal with Canada, except for less than 5 percent of the sample, which deals with European cases. Approximately one quarter of the estimates come from studies for which the majority of the data pertain to the 1970s.

Table 8.2: List of explanatory variables

Variable	Number of Observations
1) Income indicator	
Net farm income (omitted)	16
Government payments	42
Market revenue	36
Domestic market revenue	24
Foreign market revenue	24
Cash receipts (market revenue + government payments)	15
Net farm income excluding government payments	18
Return to land	43
2) Modelling	
Pure asset pricing model (omitted)	194
Hedonic variables included	24
3) Expectations	
Naïve (omitted)	114
Lagged income	54
(Weighted) average of lagged income for prior years	50
4) Type of elasticity	
Short-run (omitted)	196
Long run	22
Calculated elasticities	175
Directly obtained elasticities (double log specification)	143
5) Important variables included	
Lagged land price	41
Capital gains	31
6) Type of agricultural product	
Not specified (omitted)	70
Corn and soybeans	138
Grain and wheat	10
7) Estimator	
OLS (omitted)	127
Non-OLS (correcting for heteroscedasticity, serial autocorrelation,etc.)	49
Systems estimator	42
8) Spatio-temporal coverage	
USA (omitted)	159
Canada	51
Europe	8
Cornbelt	42
1970s (over 50% of the observations pertain to the 70s)	52
9) Type of data	
National data (omitted)	29
State or provincial data	168
County or district data	21
Time series (omitted)	166
Cross section	23
Pooled	29
Land plus buildings (omitted)	185
Land only	33

As mentioned in Section 8.2, farmland prices experienced an explosive increase during the 1970s. It may hence be important to indicate this period in the meta-regression model. With respect to the *type of data*, we distinguish between different levels of spatial aggregation and time series versus cross section and pooled data. Close to 80 percent of the estimates are at the state or provincial level and use the time series format. In addition, we distinguish between estimates referring to land values only (circa 15 percent) and those including the value of buildings.

8.4 Meta-regression Analysis

The basic principle of meta-regression analysis was introduced in Subsection 5.3.4 of Chapter 5. Here, we will explain the workings of this meta-analytical tool in greater detail. The meta-regression model can be formalised as follows (Stanley and Jarrell, 1989):

$$b_j = \beta + \sum_{k=1}^{K} \alpha_k Z_{jk} + e_j \qquad (j = 1,2,\ldots S), \tag{8.4}$$

where b_j is the reported estimate of interest (in our case the land price elasticity) of the j^{th} study from a sample of S studies, β is the intercept term of the regression equation (the true value of the parameter of interest), Z_{jk} is a ($j\times k$) matrix of explanatory variables which represent the different study characteristics, α_ks are the meta-regression coefficients reflecting the biasing effect of particular study characteristics and e_j is a random disturbance term. The explanatory variables in the Z_{jk} matrix are in most cases dummy variables, indicating the presence of a particular characteristic in a study.

Chapter 5 has pointed out that meta-analysis poses a number of methodological problems. In the current chapter, we will concentrate on two methodological issues. First, we will focus on the dependency problem that occurs with multiple sampling of observations from the same study. Secondly, we will deal with the heterogeneity problem among sample observations, which may show up in varying parameters due to different sample sizes in the initial studies, or quality differences in research design, etc.

As was described in Chapter 5, dependence among the sampled observations is equivalent to multidimensional autocorrelation, which implies that an observation can be influenced by multiple other observations within the same sample. Dependency may occur *within* studies and *between* studies. Whereas within-study dependency among sampled observations is rather obvious, between study dependency may occur if different primary studies use, for example, the same data source. The meta-regression analysis in this chapter contains a number of studies that extract their information from the same data-bases, although these are not identical with respect to space and time.[44] This may result in between-study dependency among the sampled

[44] Popular data sources are the USDA data series on the value of agricultural land and buildings and the Statistics Canada-Catalogue No.21-631 on agricultural land values.

observations. As mentioned in Chapter 5, Florax (2002a) proposed spatial statistical techniques for analysing and correcting for within and between-study dependency, since dependency within and between studies is similar to the multidimensional nature of spatial correlation among regions and countries.

Adapted to land price elasticities (*LP*), the multidimensional lag operator is described as $L^{kl}LP_{ij} = \Sigma_k \Sigma_l\, w^{S}_{ij}LP_{kl}$, $\forall k,l \in$ S, where L^{kl} is the lag operator associated with the set of land price elasticities S that are potentially correlated with estimate *j* of study *i* and $w^{S}_{ij,kl}$ is a set of weights that compare potentially dependent estimates *l* of study *k* to estimates *j* of study *i*. The set of weights includes two different types: weights to account for within-study dependency $w^{W}_{ij,kl}$ and weights to account for between-study dependency $w^{B}_{ij,kl}$. Within-study weights regard all observations that are sampled from the same study. In other words, the weights are zero except when two different estimates, *j* and *l*, are sampled from the same study. In such as case, the weight is $1/J_i$-1, where J_i is the total number of estimates *J* of study *i*. Within-study weights imply that an estimate from a specific study is compared to the average of the other estimates from the same study. Note that the within-study weights matrix contains zeros on the diagonal. Between-study weights account for estimates sampled from different studies, meaning that the weights are zero except when two estimates *i* and *l* are sampled from different studies. In such a case, the weight is $1/J_i(I\text{-}1)$, where *I* is the total number of sampled studies. Between-study weights imply that estimates from specific studies are compared to the weighted average of the (estimated) means of the other studies. By definition, the rows of the within and the between-study weight matrices sum to one, except for zero-rows in the within-study matrix. These rows reflect single estimate studies, which obviously indicate the absence of within-study dependency.

Having defined the weights for within and between-study dependency, we now turn to the question of how to test whether the two types of dependencies are present in a meta-sample. The suggested procedure is the application of Moran's *I* to the residuals of the meta-regression analysis. Moran proposed this test statistic in 1950 for investigating the degree of spatial auto-correlation between certain phenomena in adjoining counties. It compares the covariance among an exogenously defined set of estimates to the variance of all estimates (Cliff and Ord, 1981).

In the context of meta-regression analysis, Moran's *I* applied to the meta-regression residuals is defined as:

$$I = \frac{n}{S_0} \cdot \frac{\overline{\mathbf{e}}'\mathbf{W}^{\mathbf{S}}\overline{\mathbf{e}}}{\overline{\mathbf{e}}'\overline{\mathbf{e}}}, \tag{8.4}$$

where $\overline{\mathbf{e}}$ is the vector of regression residuals, $\mathbf{W}^{\mathbf{S}}$ the weight matrix, either accounting for within or between-study dependence, *n* the total number of observations in the sample and S_0 the sum of the elements of the weight matrix. For a between-study weight matrix, the total number of observations is equal to the sum of elements of the matrix, indicating that the scaling factor n/S_0 equals one. For a within-study weight matrix, the factor n/S_0 is larger than one if the sample includes single estimate studies, adjusting Moran's *I* for the missing covariances for these studies.

Applying Moran's *I* to regression residual shows whether dependency among the error terms *exists*. It does not, however, show the cause of the correlation. There are two alternative models, making use of a Lagrange Multiplier test, which shed some light on the origin of the correlation. The first model is the so-called error model that investigates whether (mistakenly) omitted variables can be autocorrelated. The second model is called the lag model and it includes a lagged dependent variable among the regressors, since the observations on the dependent variable can be realised simultaneously. The two models and the corresponding Lagrange Multiplier tests are described in Appendix 8a.

An alternative version of Moran's *I*, the local Moran, can be used to visually explore the potential dependence of the dependent variables in the meta-model; in our case, these are the corrected land price elasticities. The local Moran is calculated for an individual elasticity *j* of study *i* and can be formalised as:

$$I_{ij} = \frac{n}{S_0^{ij}} \cdot \frac{\overline{LP_{ij}}\mathbf{w_{ij}}\overline{\mathbf{lp}}}{\overline{\mathbf{lp}}'\overline{\mathbf{lp}}}, \tag{8.5}$$

where $\overline{\mathbf{lp}}$ is the vector of elasticities and $\overline{LP_{ij}}$ the individual elasticities *j* from study *i*, both measured in deviations from the overall average elasticity, $\mathbf{w_{ij}}$ is the row of the weight matrix referring to estimate *j* of study *i*, and S_0^{ij} is the sum of weights in $\mathbf{w_{ij}}$. In order to identify influential clusters of similar estimates, the local Morans of the individual estimates are depicted on a scatter plot. Figures 8.2 and 8.3 show the Moran scatter plots for within and between-study dependency, respectively.

The Moran scatter plots show on their X-axes the standardised values of the estimates and on their Y-axes the standardised values of the estimates weighted for within and between-study dependency, respectively. Observations gathered in the north-east and in the south-west quadrants of the scatter plots have positive local Morans, which means that, with values above or below the average value, they contribute positively to overall autocorrelation. Accordingly, observations situated in the north-west and south-east quadrants of the scatter plots have negative local Morans meaning that they have dissimilar values that contribute negatively to overall autocorrelation.

Figure 8.2, the scatter plot for within-study dependence, shows a positive correlation between the standardised observations, which is reflected by the positive slope coefficient of the trend line, 0.145 (*z*-value 5.491). This pattern reveals that high (low) values of the observations tend to be clustered within the same study, indicating the presence of within-study dependency. Furthermore, the observations' variance along the trend line is not constant, which leads us to conclude that the meta-sample is heteroscedastic.

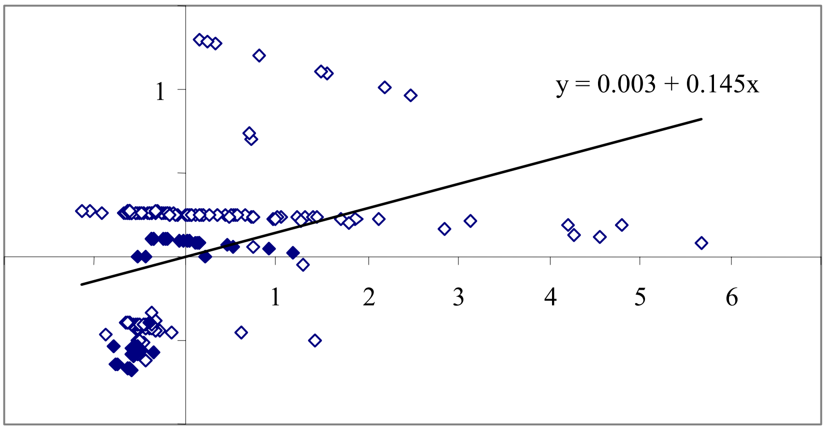

Figure 8.2: Moran scatter plot for within-study dependency

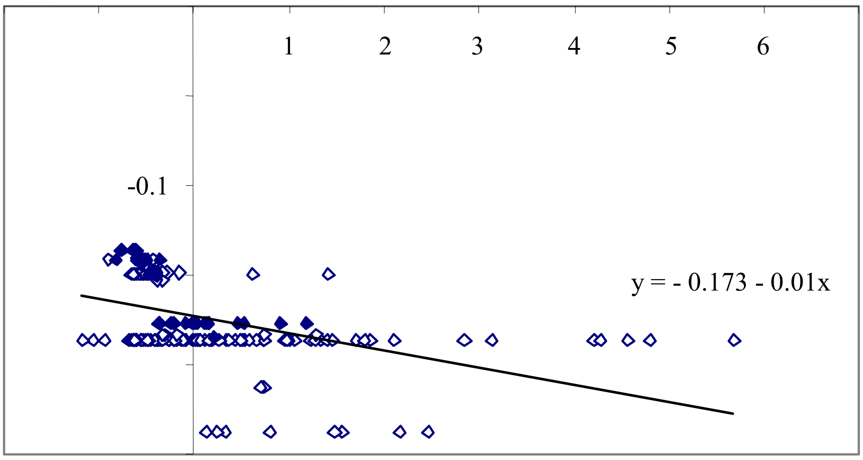

Figure 8.3: Moran scatter plot for between-study dependency

Figure 8.3, the scatter plot for between-study dependency, shows a slightly downward sloping trend line represented by the relatively low slope coefficient of -0.01 (*z*-value -2.357), which implies a low degree of negative autocorrelation. The resulting between-study dependency is therefore rather low and may be virtually ignored. Between-study dependency due to sampling from the same data sources may be of minor importance. It should be noted that visual inspection of within and between-study dependency only refers to the dependent variable, namely the corrected land price elasticities. Since the meta-model incorporates different study and/or observation characteristics, within and between-study dependency may already be corrected for and thus may no longer appear in the regression residuals. This will be tested by the Lagrange Multiplier tests in the meta-regression analysis. The results of these tests are included in the following section.

The Moran scatter plot is also an appropriate tool for identifying outliers, i.e., observations that are further than two standard deviations away from the mean, which is represented by the origin. Both scatter plots show that there are a number of observations that are further than two standard observations away from the origin. We identify ten observations as outliers and have excluded them from the data set, as has been mentioned in the previous section.

Let us now turn to the second methodological issue, heterogeneity among sample observations. It was pointed out in Chapter 5 that heterogeneity arising from differences in study characteristics, such as the geographical and the temporal setting or research design, can be accounted for by an adequate specification of the meta-regression model. However, heterogeneity also exists due to inherent heteroscedasticity arising from the differing numbers of observations on which the underlying studies, and hence the estimated elasticties and their standard errors, are based. Statistical theory says that estimates obtained from large data sets are more precise than those obtained from small data sets. In a meta-regression analysis, a way of accounting for differences in the accuracy of the estimates is to weight each observation by its standard error. Unfortunately, not all underlying studies report standard errors of estimates. Furthermore, some elasticities in our meta-sample are calculated on the basis of absolute change rates and additional information in the underlying studies.[45] In the current meta-regression analysis, we account for heteroscedasticity by means of a heteroscedastic error model, in which we weight the model with a variable reflecting the number of observations in the underlying studies. This weighing variable consists of five categories. The first category includes all elasticities that are based on less than 20 observations, the second (third, fourth) category includes elasticities based on 20 to 30 (30 to 45, 45 to 100) observations and the fifth category includes estimates based on more than 100 observations.

The subsequent section presents the results of two models. Model A is the extended version, in which all characteristics of the underlying studies are specified in detail. Model B is a smaller version and uses only those variables that account for the major methodological differences in the agricultural land price literature as described in Section 8.2, such as how to define agricultural income, how to include expectations and whether a model has a hedonic character. Comparing the results from the two

[45] In order to derive the standard errors of a posteriori calculated elasticities, we would require the complete original data set used in the underlying study.

models may indicate whether more precise model specification reduces the incidence of dependency among observations.

8.5 Results

Table 8.3 shows the results of the various meta-regression analyses. We will first discuss the results of Model A, which are given in the first two columns of Table 8.3. Starting with the regression diagnostics concerning within and between study dependency, the table shows in Model A1 that for within-study dependency Moran's *I* is significant and positive. However, neither the error nor the lag model turns out to be significantly different from the original model. It can thus be supposed that the significance of Moran's *I* can be fully ascribed to heteroscedasticity, which is supported by the high significance of the Koenker-Bassett test. Model A2 corrects for heteroscedasticity as it was described in the previous section. A comparison of the magnitude and significance levels of the coefficients in Model A1 and A2 leads to the conclusion that they are rather stable. For this reason, we will only refer to the results of Model A2 in the following discussion.

The results must be interpreted as deviations from the base model, in which the omitted categories are included in the constant term. The omitted categories in this analysis are i) net farm income, ii) naïve expectations, iii) short-run elasticity, iv) elasticity calculated 'by hand', v) when none of the three important variables are included in the model, vi) OLS, vii) when agricultural production is not specified, viii) USA, ix) national data, x) time series data, xi) when the land price series is for agricultural land and buildings.

Concerning the first group of variables, the land price elasticities stemming from studies that use the income indicators '*government payments*', '*total farm cash receipts*' and '*net farm income excluding government payments*' are significantly different from '*net farm income*', the indicator in the base model. The positive coefficient of the government payments indicator indicates that land prices are more elastic if the change in net farm income is the result of changes in government payments. In other words, land prices seem to react positively to changes in government payments. Accordingly, the indicator net farm income excluding government payments is relatively more inelastic. The indicator total farm cash receipts, which is market revenues plus government payments, is relatively less elastic as well. This may be because this income indicator mainly stems from Canadian studies. The coefficient of the variable representing Canadian studies also shows a significantly negative sign leading us to draw the conclusion that land markets in Canada seem less elastic than those in the USA, which is included in the base model. Another significantly negative result in the eighth group of variables can be found for those observations based on data from the US cornbelt, indicating less elastic land markets.

Table 8.3: Results of meta-regression analysis

		A1[1)]	A2[2)]	B1[1)]	B2[2)]	B3[2)]
ρ		--	--	--	0.312*** (3.121)	0.249*** (2.530)
Constant		0.656** (2.424)	0.554** (2.333)	0.254* (1.671)	0.140 (0.929)	0.203* (1.547)
1) Income Indicator	Government payments	0.387* (1.723)	0.447** (2.359)	0.56*** (3.532)	0.502*** (3.302)	0.491*** (3.584)
	Market revenue	-0.309 (-1.322)	-0.288 (-1.454)	-0.301** (-1.94)	-0.239* (-1.608)	-0.277** (-2.066)
	Domestic market revenue	-0.061 (-0.248)	-0.004 (-0.018)	0.214 (1.222)	0.142 (0.848)	0.080 (0.612)
	Foreign market revenue	-0.059 (-0.24)	0.003 (0.013)	0.216 (1.233)	0.144 (0.850)	0.104 (0.506)
	Total farm cash receipts	-0.643** (-1.958)	-0.559** (-1.954)	-0.621*** (-3.749)	-0.533*** (-3.270)	-0.619*** (-3.685)
	NFI excl. government payments	-0.541** (-1.943)	-0.521** (-2.081)	-0.061 (-0.397)	-0.112 (-0.757)	-0.130 (-0.870)
	Returns to land	-0.242 (-0.962)	-0.252 (-1.167)	-0.054 (0.731)	0.016 (0.915)	-0.025 (-0.187)
2) Modelling	Hedonic variables included	0.024 (0.117)	0.021 (0.121)	0.207* (1.826)	0.170* (1.577)	0.166* (1.833)
3) Expectations	Lagged income	-0.008 (-0.069)	-0.012 (0.923)	-0.162* (-1.734)	-0.155* (-1.745)	-0.182** (-2.141)
	weighted average of lagged income in prior years	0.188 (0.967)	0.222 (0.204)	0.293* (1.922)	0.270* (1.848)	0.296** (2.123)
4) Type of Elasticity	Long run	0.517*** (4.436)	0.561*** (5.455)	0.536*** (4.655)	0.524*** (4.786)	0.542*** (5.401)
	Directly obtained (double log)	-0.127 (-1.059)	-0.102 (0.339)	--	--	--
5) Important Variable	Lagged land price	-0.499** (-2.429)	-0.397** (-2.231)	--	--	--
	Capital gains	0.122 (0.742)	0.183 (1.238)	--	--	--
6) Type of agricultural product	Corn and Soybeans	0.977*** (3.282)	0.985*** (3.64)	--	--	--
	Cereals	0.500** (1.975)	0.541** (2.349)	--	--	--

7) Estimator	Non OLS	0.220* (1.844)	0.181* (1.714)	--	--	--
	Systems estimator	-0.100 (-0.481)	-0.032 (0.853)	--	--	--
8) Spatio-temporal coverage	Canada	-0.483** (-1.972)	-0.519** (-2.486)	--	--	--
	Europe	-0.392 (-1.263)	-0.322 (-1.134)	--	--	--
	Cornbelt	-0.497*** (-4.212)	-0.471*** (-4.194)	--	--	--
	1970s	-0.047 (-0.599)	-0.079 (-1.068)	--	--	--
9) Type of data	State or Provincial data	-0.421* (-1.691)	-0.437* (-1.902)	--	--	--
	County or district data	-0.615* (-1.722)	-0.567* (-1.798)	--	--	--
	Cross section data	0.585** (2.31)	0.602*** (2.703)	--	--	--
	Pooled data	0.302* (1.708)	0.318* (1.884)	--	--	--
	Land only	0.437*** (2.952)	0.409*** (3.169)	--	--	--
R^2 (R^2-adjusted)		0.501 (0.43)	0.51	0.361 (0.327)	0.374	0.385
F-test		7.054***		10.58***		
Koenker-Bassett test for heterscedasticity		52.289***		58.752***	102.371***3)	
Within Dependence	Moran's *I*	4.047***		4.497***		
	Lagrange Multiplier (error)	0.009	0.008	6.191**		
	Lagrange Multiplier (lag)	0.540	0.850	8.063***		
Between Dependence	Moran's *I*	0.252		0.571		
	Lagrange Multiplier (error)	0.954	0.133	0.371		
	Lagrange Multiplier (lag)	0.123	0.210	0.561		
Number of observations		218	218	218	218	218

1) Values in parenthesis are t-values; 2) Values in parenthesis are z-values; 3) Breusch-Pagan test
(*, **, *** indicates significance at 10%, 5%, and 1% levels respectively)

From the third group of variables, the coefficient signifying long term elasticities is, according to the theory, significantly positively different from the short run elasticities. Intuitively, the inclusion of a lagged land price variable within a model suggests significantly less elastic land price elasticities, since this variable absorbs a large part of the capitalisation effect. Additional interesting results can be found in the seventh group of variables. Estimates that are based on corn and soybeans or cereals data turn out to be more elastic than estimates based on non-specified data. In other words, land prices seem to be more sensitive to changes in income (either through market or government payments) generated by the production of these crops than to changes generated by agricultural production in general. Furthermore, estimates based on cross section data are significantly positively different from time series data. This is in accordance with the theory of Kuh (1959), who showed that cross section elasticties are generally larger than time series elasticities since they tend to estimate long run effects.

Estimates from State or Provincial and county or district data are significantly negatively different from national data. These results counter Burt's argument that estimates from national data are biased downwards (see Section 8.2). Finally, estimates based on data series on agricultural land alone are significantly positively different from estimates based on data series on agricultural land and buildings. This indicates that the prices of agricultural land and buildings tend to be more stable than those of agricultural land alone.

It is striking that in Model A, neither the expectation variables nor the variable indicating a hedonic character of the model is significantly different from the base model. Let us now turn to Model B in order to find out how these variables behave in a simplified version of Model A.

Again considering the regression diagnostics concerning within and between-study dependency, in Model B not only Moran's *I* but also the lag and the error model for within-study dependency are significant. This indicates that in the less detailed specification of the model, within-study dependency is indeed present. Since the lag model is more significant that the error model, we have decided to rerun the model accounting for lag dependence (Model B2). The Breusch-Pagan test still suggests a heteroscedastic error term. We corrected for this error by employing the same procedure that we used in Model A. The correctness of the lag model is represented by the significance of the autoregressive parameter ρ. In the description of the results, we again refer only to the outcome of Model B3.

It is striking that the magnitudes of the coefficients of the first group of variables remain more or less stable. However, whereas the indicator '*net farm income excluding government payments*' becomes insignificant, the indicator '*market revenue*' becomes negatively significantly different from the base case. This indicates that land prices are less elastic with respect to the changes in net farm income resulting from changes in market revenues.

Also, the coefficients of the two expectation variables result in significantly different estimates in Model B3, albeit with opposite results. Even the coefficient of the variable representing a hedonic character is significantly different. However, theoretically, one would expect a negative sign, since hedonic studies generally include more explanatory variables in their models and are usually conducted in more populated areas, where the influence of agricultural income would be expected to be less important.

8.6 Discussion and Conclusions

This chapter has presented a meta-regression analysis of the capitalisation effect of agricultural income into land prices including a method for testing and correcting for within and between-study dependency. The primary studies underlying the meta-regression analysis use varying agricultural income indicators for their estimations. In order to compare these estimates in a meta-regression analysis, we have proposed a method for converting all estimates into the same income indicator, net farm income. In this way, all estimates represent the change in land prices due to the change in net farm income, but by accounting for the original income indicators by means of dummy variables, we were able to find the actual source of net farm income changes. The various income indicators may shed light on the question of whether different sources of agricultural income have different effects on agricultural land prices. The results of the meta-regression analysis show that land prices tend to be more elastic with respect to changes in government payments than with respect to pure market revenues or net farm income in general. If we assume that market revenues include only the price support component of agricultural policy and government payments only the direct income support payments, we can conclude that direct income support leads to more inflation of land prices than price support policies. The ongoing agricultural policy reform in most industrialised countries, i.e., switching from price support to direct income support, would not, according to this analysis, lead to a decrease in land prices and a subsequent increase in land market mobility. However, it is important to note that the estimates in the underlying studies stem from a period of agricultural policy when government payments were often coupled with agricultural land. This implies that the results cannot simply be transferred to the current situation, in which income support is supposed to be decoupled from agricultural land.

The meta-regression analysis additionally addresses the dependency problem arising from multiple-sampling of observations from the same study. A comparison of an extended model and a reduced model reveals that careful specification in the meta-model, which is realised in the extended model, can alleviate dependency among the sampled observations. In a properly specified model, dependency may be considered insignificant.

Appendix 8a. Error and Lag Model

The error model is formalised as:

$$\mathbf{t} = \mathbf{X\beta} + \boldsymbol{\varepsilon}, \text{ and } \boldsymbol{\varepsilon} = \lambda \mathbf{W}^{\mathrm{S}} \boldsymbol{\varepsilon} + \boldsymbol{\mu}, \tag{8a.1}$$

where λ is the autoregressive parameter indicating the magnitude of the unspecified dependence within or between studies and μ a well-behaved error term. The corresponding Lagrange Multiplier test is defined as:

$$LM_{\lambda} = \frac{1}{c} \cdot \frac{\mathbf{e}'\mathbf{W}^{\mathrm{S}}\mathbf{e}}{s^2}, \tag{8a.2}$$

where s^2 is the maximum likelihood variance $\mathbf{e}'\mathbf{e}/n$, and c = tr ($\mathbf{W}^{\mathrm{S}'}\mathbf{W}^{\mathrm{S}} + \mathbf{W}^{\mathrm{S}^2}$), with tr as the matrix trace operator. The test is asymptotically χ^2 distributed with one degree of freedom. According to Anselin (1988), a correlated error structure does not result in biased estimates, but in inefficient ones.

The lag model is formalised as:

$$\mathbf{t} = \rho \mathbf{W}^{\mathrm{S}} \mathbf{t} + \mathbf{X\beta} + \boldsymbol{\mu}, \tag{8a.3}$$

where ρ is the autoregressive parameter indicating the magnitude of the dependence of the estimates within or between studies. The corresponding Lagrange Multiplier test is similar to the test of the error model, since it has the same asymptotic distribution. This test is defined as:

$$LM_{\lambda} = \frac{1}{nJ_{\rho \cdot \beta}} \cdot \frac{\mathbf{e}'\mathbf{W}^{\mathrm{S}}\mathbf{t}}{s^2}, \tag{8a.4}$$

where $J_{\rho \cdot \beta} = [(\mathbf{W}^{\mathrm{S}}\mathbf{Xb})'\mathbf{M}(\mathbf{W}^{\mathrm{S}}\mathbf{Xb}) + cs^2] \,/\, ns^2$ is part of the estimated information matrix, $\mathbf{M}$ the projection matrix ($\mathbf{I} - \mathbf{X}(\mathbf{X}'\mathbf{X})^{-1}\mathbf{X}'$) and **b** the OLS parameter vector. The endogeneity issue implied in the lag model is more serious than the correlated error structure in the previous model, since the OLS estimator is biased and inconsistent.

PART III

RETROSPECT AND PROSPECT

CHAPTER 9

SUMMARY AND CONCLUSIONS

9.1 Overview

McMillan (2000) states that "*[s]ynthesizing scattered research adds as much value, and requires as much imagination and creativity, as doing the original research*". The additional value of synthesising research can be ascribed to the various underlying conditions that determine the nature of the object being investigated in the individual studies. In 1945, Hayes noted that the scientific profession has tended to neglect a very important body of knowledge that was not considered scientifically relevant for creating general rules. This important body of knowledge consists of unorganised knowledge about particular temporal and spatial circumstances. Hayes emphasised that the ongoing changes and developments in an economy result from accumulation of small changes that occurred in different places and at different times; these cannot be identified by investigating macro data. Synthesising scattered research that was carried out in different places and at different times can address Hayes' concern for the neglected body of knowledge. Incorporating spatial and temporal variables in a research synthesis can give insight into the influence of these variables on the final result.

The importance of *time* and *place* for agricultural land use and agricultural policy in western industrialised countries has been emphasised in the previous chapters. The *time* dimension is of particular relevance to changing preferences in a society. At the time when Hayes pointed out the importance of time and place, national food security was the most important objective of agricultural policies. Shortly after the Second World War, the general public was concerned mainly with basic needs, such as sufficient food supply and housing. Due to economic development and stabilising policies, basic needs have been satisfied, leading to changes in society's preferences. In accordance with the Kuznets curve, societies start considering environmental issues once a certain level of wealth has been attained. The types of agricultural policy that were introduced after the Second World War have been directed towards productivity enhancement, increases in scale and specialisation and intensification of production processes in order to comply with the policy objective of securing food supply. These type of policy have been criticised increasingly because of its negative side-effects, such as the degradation of environmental resources, high budgetary costs incurring through supportive agricultural policy measures and risks to human health arising from several causes, such as BSE, chemically-contaminated animal feed or genetically-modified food. Nowadays, the public appreciates other services from agriculture, namely, the provision of open space, characteristic landscape elements, wildlife habitat and other environmental amenities.

The importance of *place* in the context of agricultural land use becomes obvious when we consider the heterogeneity of land, which has been identified as a significant characteristic that distinguishes land from other capital goods. The heterogeneity of land may be caused by differences in soil quality and location, which determine the suitability of land for particular production processes. The production value generated by a plot of land of a certain quality and at a certain location determines, in turn, the market value of this plot of land. The heterogeneity of land is also created by environmental amenities that determine the recreational value of a particular plot of land or indicate its value for nature and wildlife. These values are, however, mostly non-market values, which implies that they are not taken into account in farmers' agricultural land use decision making. Consequently, the value of the *deterioration* of these types of amenities is not taken into account in land use decision making. The fact that market values for these amenities do not exist results from the fact that most of these amenities have public good characteristics for which property rights are not defined.

In the course of economic development, the general public increasingly appreciates public good characteristics, i.e., the positive externalities of agricultural land use, and resents public 'bads', i.e., the negative externalities. As a response to the changing societal preferences, recent developments in agricultural policy indicate that policy-makers have an incentive to restructure the agricultural sector, in order to reduce the generation of negative externalities and stimulate the creation of positive externalities. Agricultural and environmental policies introduced to stimulate and accompany the restructuring of the agricultural sector are the focus of this dissertation. The theoretical and methodological background of the issues described are given in Part I, which includes Chapter 2, 3, 4 and 5. Part II includes the empirical part of this dissertation.

The empirical part investigates three different types of agricultural and environmental policies. The empirical applications have two general objectives. First, they serve as illustrations of different methods of quantitative research synthesis. Second, they provide some empirical evidence of the effects of agricultural and environmental policies on agricultural land use and the environment.

Application A deals with co-operative agreements between water supply companies and farmers in Bavaria, Germany. These agreements are aimed at reducing the agricultural pollution of groundwater used as an input for drinking water production. Co-operative approaches in policy-making are based on the Coase Theorem, which considers bargaining between polluter and victim without government intervention. Methodologically, Application A is identified as a comparative analysis of case studies, and it is investigated with the help of rough set analysis, a classification technique that attempts to identify regularities in classified data, pointing out the relative importance of specific attributes and discovering logical deterministic inference rules.

Application B focuses on agri-environmental policy programmes in the European Union. Agri-environmental policy programmes were introduced along with the Mac Sharry Reform of the CAP in 1992. EU Agri-environmental policy programmes must consider regional differences in geographical conditions and agricultural production structures throughout the European Union. The actual elaboration and implementation of the policy programmes takes place on a national or a sub-national level, since these administrative levels have better information about local circumstances and the relative importance of particular environmental issues. A major objective of agri-environmental policy programmes is to stimulate the production of positive externalities from agricultural land use. Application B has been identified as a meta-analysis, and is studied with the help of conventional meta-analytical tools, which allow the comparison of the behaviour of an experimental group (the group of farmers who participate in an agri-environmental policy programme) and that of a control group (the group of farmers who do not participate in a programme). The behaviour under investigation refers to the change rates in three agricultural indicators over a five-year period (1993-1997). The three indicators are ‘use of mineral fertiliser’, ‘livestock density’ and ‘grassland per Utilisable Agricultural Area’. The tools that have been applied are ‘combining effect size estimates’ and a moderator analysis.

Application C is concerned with the effects of agricultural income on land prices. Land prices are determined by the expected future returns to land. Agricultural policy aiming at stabilising and supporting market prices and agricultural income causes farmers to have optimistic expectations about future returns. Since land is the production factor with the least elastic supply, returns to agricultural production, supported by governmental aid, capitalise most in land, which leads to inflation of land prices. Inflated land prices increase farmers’ capital costs, which may lead to an intensification of production in order to re-earn these costs. Application C reviews 19 individually-performed studies that estimate elasticities of land prices with respect to agricultural income in the US, Canada and Europe. These studies differ not only in terms of their geographical and temporal aspects, the type of agricultural production considered, and the structure of the data or the estimation technique being applied, but also in terms of the precise definition of the agricultural income indicator used to calculate the elasticities. The analytical challenge in Application C was to find a method for making the individual elasticities from the 19 studies comparable. Application C has been identified as a strictly defined meta-analysis. It employs meta-regression analysis. Additionally, tools from spatial statistics are applied in order to account for the dependency problem arising from multiple sampling of observations.

The following section reviews the conclusions that were reached in the different analyses in the previous chapters.

9.2 Conclusions

The following conclusions focus on two topics. First, we want to draw policy lessons from the empirical investigations in this dissertation. Second, we want to review our experiences with applying comparative and meta-analytical techniques to the field of agricultural land use and policy analysis. This section addresses the research questions that were posed in the introduction to this dissertation.

9.2.1 Policy lessons

The empirical part of this dissertation has investigated three examples of agricultural and environmental policy. The analysis of co-operative agreements between farmers and water suppliers (Application A) in *Chapter 6* suggests a number of factors that influence the effectiveness of co-operative agreements as an alternative policy instrument for limiting nitrate pollution in groundwater. The analysed data strongly indicate that co-operative agreements including a restriction that requires farmers to use the land under agreement as permanent grassland, have a limiting effect on nitrate pollution in groundwater. Additionally, this restriction appears to be particularly important in combination with the year in which the co-operative agreement was established. In general, the analysis reveals that the "oldest" co-operative agreements, i.e., those that were established ten to fifteen years ago, are more likely to have a positive effect on groundwater quality. This is the case even without additional restrictions besides the general ones on fertiliser use, such as its amount and the time of its application. In combination with additional restrictions, particularly the restriction 'permanent grassland' and the restriction requiring farmers to maintain permanent soil cover, the results indicate that co-operative agreements may also be effective in the shorter term. It can hence be hypothesised that there is a trade-off between the number of years a co-operative agreement exists and its stringency. Further results showed that smaller shares of arable land in total agricultural land under agreement are more likely to be associated with decreasing nitrate levels in groundwater.

The analysis in *Chapter 7* investigates the effectiveness of agri-environmental policy programmes in the European Union (Application B). As opposed to the analysis in Chapter 6, which used the actual state of the environment as an indicator for measuring policy effectiveness, the analysis in Chapter 7 employes a behavioural indicator type, which reveals information about the changes in farming practices stimulated by policy. Chapter 7 uses three different behavioural indicators, namely, 'use of mineral fertiliser', 'livestock density' and 'grassland area per Utilisable Agricultural Area'. Although the analysis can be considered exploratory since it is based on a limited number of observations, some general insights have been gathered. Overall, the analysis has indicated that agri-environmental programmes have a positive effect on the behaviour of farmers participating in these programmes. Higher than average premiums paid per hectare within the framework of an agri-environmental policy programme seem to affect farmers' behaviour with respect to livestock densities. The results of the effect size analysis need to be interpreted as follows: Higher premiums paid per hectare seem to result in increasing proportions of participating farmers that show higher change rates with respect to reducing livestock density than the average change rates of non-participating farmers.

Concerning the influence of the average premium per hectare paid on the use of mineral fertiliser, an interesting result has been found. Higher average premiums do not necessarily lead to larger numbers of participating farmers with change rates higher than the average change rate of non-participating farmers. This is a favourable result considering that agri-environmental programmes are meant to *stimulate* environmentally friendlier farming methods. Farmers, once they have been informed and advised within the framework of an agri-environmental policy programme, may realise that reducing (optimising) their use of mineral fertiliser is advantageous to their farms' financial situation, even without compensation payments.

Furthermore, it appears that the farms' intensity level with regard to livestock density and mineral fertiliser influences the number of participating farmers with higher change rates than the average change rate of non-participating farmers. Agri-environmental policy programmes have often been criticised for reaching only extensive farms that not necessarily need to change farming practices. The described result, however, indicates that agri-environmental programmes also reach the more intensive farms, i.e., those farms that need to change farming practices in order to reduce pressure on the environment.

Interpreting the results revealed in Chapter 6 and 7 requires that we consider one important fact. Both types of policies are voluntary for farmers. This implies that the farmers who participate in a co-operative agreement or an agri-environmental policy programme are not randomly assigned, but instead participation occurs through self-selection. Farmers who are willing to participate in an agreement or programme might be willing to change farming practices towards more environmentally friendly methods, even without the influence of the agreement or programme. It must, however, be mentioned that such voluntary programmes play an important role in increasing awareness and knowledge of the environmental problems occurring as a result of agricultural production. Voluntary programmes are much more clearly aimed at the direct involvement of farmers in finding appropriate solutions for reducing pressure on the environment. A frequently-used synonym for the term 'voluntary programmes' is the term '*stimulation* programme'. Obviously, the programmes are supposed to stimulate farmers to adopt environmentally sound farming practices, which may not occur if such programmes would not exist.

Chapter 8 analyses the capitalisation of agricultural income into land prices. The studies involved in the meta-analysis of Chapter 8 use different types of income indicators to estimate the effect of agricultural income on land prices. By comparing the estimates based on the different types of income indicators, the analysis attempts to show whether different sources of agricultural income have different effects on agricultural land prices. The results revealed that income from direct government payments shows higher capitalisation rates than income from market revenue, which is assumed to include only the price support component of agricultural policy. Direct government payments hence lead to greater inflation of land prices than price support. Ongoing agricultural policy reforms in most industrialised countries involve a switch from price support to direct income support. On the basis of the data analysed in Chapter 8, it can be concluded that such a reform would not lead to a decrease in agricultural land prices. It must be mentioned, however, that the studies in the meta-analysis were carried out in a period when direct government payments were often coupled with agricultural land. In order to obtain less inflated land prices and, subsequently, an increase in land market mobility, it is thus important to decouple direct government payments form agricultural land in the ongoing agricultural policy reforms.

9.2.2 Insights from quantitative research synthesis

The empirical applications in Chapters 6, 7 and 8 presented three different types of research syntheses. The types of research synthesis were selected according to the data available for the investigations in these chapters. Chapter 5 provided the methodological framework for determining the type of analysis that should be employed for investigating particular types of data. Three different types of research synthesis have been identified, namely independent narrative literature review, comparative analysis of case studies and meta-analysis. The latter two types are quantitative types of research synthesis, which was the focus of this dissertation. The main difference between a comparative analysis of case studies and a meta- analysis is the level at which the data are aggregated or statistically summarised. Whereas a comparative analysis of case studies makes use of 'raw', 'individual' or primary data, a meta-analysis can be distinguished because it makes use of aggregated or statistically summarised data, such as correlation coefficients, elasticities or standardised mean differences. It is important to emphasise that, in a meta-analysis, the original primary data are not available. A condition that should be fulfilled for both types of quantitative research synthesis is that the observations in the data set for the research synthesis must be meaningful when regarded individually. In other words, the individual case studies, articles, research protocols or other type of primary research have to be informative by themselves and not only when being compared to other observations.

Chapter 6 contains a comparative analysis of case studies, which employs rough set analysis as a tool for research synthesis. Rough set analysis is a non-parametric classification technique that aims at detecting regularities in classified data by determining the relative importance of specific data attributes and by discovering possible deterministic inference rules in the form of "if-then" statements. Along with its non-parametric character, another advantage of rough set analysis is its ability to handle imprecise and uncertain information. Rough set analysis involves a combination of methodological issues, which have been addressed in Chapter 6. The first issue deals with the influence of different categorisation methods on the results of the rough set analysis. The second issue evolves from the first issue and considers the potential loss of information due to data categorisation.

The potential effect of data categorisation on the final results has not yet received much attention in the application of rough set analyses to empirical policy assessment. Data categorisation is usually performed in a 'casual' way, mostly on the basis of a visual inspection of the data, but not according to strictly defined categorisation methods. It is, however, important to investigate whether the way in which the data are categorised has an effect on the final results. The analysis in Chapter 6 compares three different categorisation methods, namely, equal-frequency binning, equal-interval binning and the entropy-based method. It shows that the methods of categorising the data do affect the results. Firstly, attribute reduction of the rough set analyses based on the three different categorisation methods results in different numbers of minimal sets. Since small numbers of minimal sets imply that the data has higher 'predictive power', it can be concluded that different categorisation methods lead to different levels of 'predictive power' of the data. Furthermore, the three categorisation methods lead to different numbers of decision rules and to different combinations of condition attributes within the rules. However, in the case of the data analysed in Chapter 6, the information revealed by the decision rules (with strengths greater than 4) for the three categorisation methods is not contradictory.

In order to gain insight into the potential loss of information due to the categorisation of the data, the results of the rough set analysis were compared with those of a probit analysis. A probit analysis employs the information from every individual observation. It is assumed that a probit analysis exploits the information given by the data better than the rough set analysis. The comparison indicated that categorising the data seems to involve a loss of information. The results revealed that the greatest information loss occurred on the basis of equal-interval binning.

An important conclusion that can be drawn from the application of rough set analysis is that the data categorisation needs to be considered carefully. It has been pointed out that the 'safest' method for data categorisation is on the basis of predetermined theoretical grounds. If this condition is not fulfilled, it is advisable to perform a sensitivity analysis on the data categorisation as is shown in Chapter 6, in order to be able to draw unambiguous conclusions about the problem being analysed.

Chapter 7 contains a meta-analysis based on quasi-experimental research results that indicate differences in means between an experimental and a control group. This type of meta-analysis is mainly used in the traditional fields of meta-analytical applications, such as medical sciences or psychological research. It is not very common in economics. An interesting result revealed in Chapter 7 concerns the artificial lowering of the variance of the case study results. A large number of the original observations from the individual case studies showed insignificant results, which might have been due to the limited number of observations. By pooling the estimates across the case studies, the meta-analysis produced synthesised estimates with considerable more power than the individual case studies.

It is important to note that the type of research synthesis presented in Chapter 7 reveals information about the number of members of the experimental group that shows lower (higher) values of a particular variable than the average value of this variable of the control group. It does not reveal information about the extent to which the behaviour of the experimental group differs compared to the behaviour of the control group. This characteristic explains the popularity of this type of research synthesis in medical science and psychological research, where the outcomes of experiments are often of binary nature, i.e., healthy or sick, dead or alive.

The analysis in *Chapter 8* employs a meta-regression analysis. Two advantages of meta-regression analysis need to be mentioned when we compare it to the types of research synthesis in Chapters 6 and 7. In comparison with Chapter 6, meta-regression analysis better exploits the data than rough set analysis, since it employs information of each individual observation. In comparison with Chapter 7, meta-regression analysis is able to handle multiple variables, taking into account variations in the dependent variable under investigation. Furthermore, economic researchers are generally familiar with regression analysis. Thus they understand meta-regression analysis better than other types of research synthesis. However, performing a meta-regression analysis requires a certain minimum number of observations in order to derive statistically sound conclusions. If this condition is not fulfilled, other types of research synthesis are an appropriate alternative.

The meta-regression analysis in Chapter 8 addresses a major methodological problem inherent to meta-analysis: the dependency problem arising from multiple sampling of observations. Dependency among meta-observations may be considered similar to multidimensional autocorrelation in a spatial context and it may appear *between* as well as *within* studies. Because of its similarity to spatial autocorrelation, the dependency problem in the meta-sample was analysed with the help of spatial statistical techniques, i.e., Moran's *I*, the spatial error model and the spatial lag model applied to the meta-regression residuals. Two model specifications were estimated. First, the extended model included the full range of moderator variables, so that variations in the dependent variable were explained as precisely as possible. Second, the reduced model included only moderator variables that explain major theoretical differences. On the basis of the data analysed, some interesting conclusions can be drawn. Whereas dependency among observations is present in the reduced model, the test on dependency is insignificant for the extended model. In other words, a careful specification of the meta-model, which was realised in the extended model, can correct for dependency among observations in the meta-sample, such that more sophisticated techniques to correct for dependency may not be required.

In addition to the specific insights obtained from the three individual types of research synthesis, some general conclusions concerning research synthesis in agricultural and environmental policy assessment can be drawn. Performing research synthesis requires careful reading of the studies or case studies to be included. All study characteristics need to be captured in as much detail as possible, which requires a thorough understanding of the problem being analysed, its theoretical background and the estimation methods being applied. It can thus be stated that performing a research synthesis enhances the researcher's knowledge on a particular issue more than doing a primary analysis, where the full exploitation of the available literature is not necessarily required.

In the context of agricultural and environmental policy evaluation, methods of research synthesis can assist in gaining insight into spatial and regional factors, which may determine the success or the failure of a particular type of policy. This can be achieved by summarizing case studies that investigate a certain type of policy applied to different regions and incorporating the variables that describe the regional circumstances in the analysis. The results of the research synthesis indicate whether specific spatial and regional factors have a significant influence on the policy effect. These insights may, in turn, assist in recommendations about region-specific policy approaches.

9.3 Suggestions for Further Research

Usually, research on particular topics raises numerous new research questions. In this section, we want to point out a number of issues that would be interesting to investigate as a follow-up to the research carried out in this dissertation.

Chapter 5 has mentioned further objectives of meta-analysis, which were not explicitly addressed in the empirical part of this dissertation. These objectives include finding directions for new primary research and benefit transfer. It was pointed out in the previous section that doing a meta-analysis provides the researcher with fundamental knowledge about the problem under investigation. Provided that relevant data are readily available, a new primary analysis of the same problem could be performed rather easily. The structure of the available data and the precise definition of the variables included in the data set bound the researcher to specific study characteristics. It is hence difficult for the researcher to investigate the influence of different study characteristics within the primary analysis. The benefit of a previously performed meta-analysis is that the researcher has an idea of the potential effects of particular model characteristics. He or she can hence interpret the results of the primary analysis against the background information obtained from the meta-analysis.

As a follow-up on the meta-regression analysis in Chapter 8, it would be very interesting to perform a primary analysis on the determinants of agricultural land prices for the Netherlands, similar to those in the meta-analysis' underlying studies.

The Netherlands' high population density may imply that non-agricultural factors are more important for agricultural land price determination than agricultural income. From the viewpoint of benefit transfer, it would be interesting to compare the results of the new primary analysis with those of the meta-analysis. Would the meta-analysis predict the outcomes of the new primary analysis if the study characteristics of the primary analysis were plugged into the meta-model? If this were the case, the meta-model could be regarded as a sound instrument for benefit transfer.

With respect to agricultural and environmental policy analysis, the following issue invites further research. In order to show the relationship between problems discussed in the empirical chapters, it would be interesting to estimate the effects of *environmental* policies, such as co-operative agreements or agri-environmental programmes, on agricultural land prices. Do the payments involved in such policies capitalise into land prices, similar to the way other types of agricultural support payments do, which lead to land price inflation? Or, do such policies have a negative effect on land prices since conventional agricultural production is restricted, which may imply a reduction of the value of agricultural production? An additional research question relates to land market mobility. It would be interesting to find out whether decreasing land prices would indeed lead to the reallocation of intensive agricultural land to extensive uses, and to a decrease in the environmental pressure caused by agricultural production.

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SAMENVATTING

(SUMMARY IN DUTCH)

Inleiding

In dit proefschrift worden de effecten van het landbouwbeleid op agrarisch grondgebruik en het milieu onderzocht. Het voornaamste doel van het traditionele landbouwbeleid in de meeste Westerse, geïndustrialiseerde landen na de Tweede Wereldoorlog, was het veiligstellen van de voedselvoorziening. Dit doel werd gerealiseerd door intensivering, specialisatie en concentratie van de agrarische productie, die werden gestimuleerd met beleidsinstrumenten zoals prijsstabilisatie, exportsubsidies en afscherming van de binnenlandse (EU-)markt. Met behulp van dit type landbouwbeleid werd de binnenlandse (EU-wijde) voedselvoorziening succesvol veilig gesteld, maar het beleid had ook nadelen. De intensivering van de landbouwproductie ging gepaard met een toenemende druk op het milieu en de natuurlijke hulpbronnen. Naast de negatieve effecten op het milieu vormde het traditionele landbouwbeleid ook een niet geringe financiële belasting voor de overheidsbegrotingen. Een hervorming van het traditionele landbouwbeleid was daarom onvermijdelijk.

Gedurende het afgelopen decennia zijn ook de preferenties in de maatschappij veranderd. Nu de (kwantitatieve) voedselvoorziening veilig is gesteld, verschuift de belangstelling naar andere gebieden. De zorg voor het milieu, voedselkwaliteit en dierenwelzijn staan sinds het begin van de jaren negentig duidelijk hoger op de agenda. De boer wordt niet meer uitsluitend als voedselproducent gezien, maar ook als beheerder van de natuur in het landelijk gebied. De hervorming van het traditionele landbouwbeleid is daarom ook bedoeld om bij deze veranderde preferenties aan te sluiten

In deel twee van dit proefschrift worden drie verschillende beleidsinstrumenten, die de hervorming van het traditionele landbouwbeleid moeten ondersteunen, empirisch onderzocht. De drie beleidsinstrumenten zijn: beheersovereenkomsten tussen boeren en waterleidingbedrijven, de EU-landbouw/milieuverordening en de overgang van prijssteun naar directe inkomenssteun bij de Europese subsidieverlening voor boeren. Voorafgaand aan deze empirische analyses worden in het eerste deel van dit proefschrift de theoretische en methodologische grondslagen van de empirische analyses aan de orde gesteld.

Deel I: theoretische en methodologische grondslagen

De theoretische en methodologische grondslagen worden behandeld in drie hoofdstukken. Hoofdstuk 2 vormt een inleiding op het theoretische gedeelte van dit proefschrift. In dit hoofdstuk wordt het in de bovenstaande inleiding geschetste beeld met empirische gegevens en feiten onderbouwd. Daarnaast wordt een eerste overzicht gegeven van de onderzoeksmethoden die worden gebruikt in het tweede deel van dit proefschrift. In het bijzonder wordt aandacht besteed aan vergelijkende en meta-analytische onderzoeksmethoden, die tezamen de kwantitatieve onderzoekssynthese vormen.

Hoofdstuk 3 richt zich op de economische aspecten van (agrarisch) grondgebruik en in het bijzonder op de aspecten die aanleiding geven tot interventie door de overheid. Begrippen die in dit hoofdstuk besproken worden, zijn: externaliteiten, eigendomsrechten, de optimale allocatie van grond tussen verschillende gebruikers en het bepalen van de economische waarde van grond. Een belangrijk theoretisch inzicht dat uiteengezet wordt, is dat ongewenste externe effecten van grondgebruik met name te wijten zijn aan het ontbreken van eigendomsrechten.

In Hoofdstuk 4 worden enkele aspecten van de beleidsvorming nader toegelicht. Duurzaamheid en duurzame ontwikkeling worden op velerlei beleidsterreinen als het voornaamste beleidsdoel aangegeven. Een belangrijk probleem is echter dat het vaak ontbreekt aan een duidelijke invulling van de term ‘duurzaamheid’. Dit probleem wordt in dit hoofdstuk verder uiteengezet. Daarnaast wordt in hoofdstuk 4 aandacht besteed aan de rol van de verschillende actoren in het proces van beleidsmaken en verschillende overheidsniveaus waarop beleid gemaakt en uitgevoerd kan worden. Verder wordt een overzicht gegeven van een aantal beleidsinstrumenten. Met name het instrument van belastingen en subsidies en communicatieve instrumenten worden nader toegelicht.

Hoofdstuk 5 gaat in op de definitie van kwantitatieve onderzoekssynthese. In het kader van dit proefschrift wordt onderscheid gemaakt tussen twee vormen van kwantitatieve onderzoekssynthese: vergelijkende analyse van case studies en meta-analyse. Een belangrijke factor die het verschil tussen deze twee vormen van kwantitatieve onderzoekssynthese bepaalt, is de structuur van de data. Bij een vergelijkende analyse van case studies wordt gebruikt gemaakt van primaire oftewel niet statistisch-geaggregeerde data. Bij een meta-analyse zijn de primaire data niet beschikbaar. Men moet hier gebruik maken van statistisch samengevatte data zoals, elasticiteiten of ‘standardised mean differences’. Het hoofdstuk beschrijft daarnaast een aantal methoden die bij de kwantitatieve onderzoekssynthese toegepast kunnen worden.

Deel II: empirische analysen

In het tweede deel van dit proefschrift worden drie verschillende beleidsinstrumenten onderzocht. In Hoofdstuk 6 worden vrijwillige beheersovereenkomsten tussen waterleidingbedrijven en boeren ten behoeve van het terugdringen van nitraatvervuiling van grondwater bestudeerd. Beheersovereenkomsten verschillen van traditionele dwingende beleidsinstrumenten (regelgeving), omdat bij beheersovereenkomsten de vervuilende partij (de boeren) en de benadeelde partij (het waterleidingbedrijf) samenwerken om tot oplossingen voor het probleem in kwestie te komen. De analyse in dit hoofdstuk is gebaseerd op een enquête die in het jaar 2000 werd gehouden onder 75 waterleidingbedrijven in de Duitse deelstaat Beieren. De analyse heeft twee doelen. Ten eerste wordt nagegaan of de beheersovereenkomsten inderdaad een positief effect hebben op de grondwaterkwaliteit. Het tweede doel is van methodologische aard. De gegevens uit de enquête zijn geanalyseerd met behulp van 'rough set'-analyse, een non-parametrische methode om structuren in geclassificeerde data te achterhalen. Er wordt met name ingegaan op twee methodologische vraagstukken die verbonden zijn aan 'rough set'-analyse. Het eerste vraagstuk heeft te maken met de manier waarop de gegevens gecategoriseerd worden. Aan de hand van drie classificatiemethoden ('equal-frequency binning', 'equal-interval binning' en 'entropy-based') wordt onderzocht of verschillende manieren van categoriseren tot significant andere uitkomsten leiden. Het tweede vraagstuk richt zich op het verlies van informatie als gevolg van de indeling in categorieën.

Het effect van beheersovereenkomsten op grondwaterkwaliteit kan als volgt worden samengevat. Overeenkomsten met de extra restricties om het land uitsluitend als grasland te gebruiken en te zorgen voor permanente bodembedekking, leiden tot een afname van het nitraatgehalte in grondwater. Overeenkomsten die al langer dan 15 jaar werkzaam zijn, lijken een positief effect op de waterkwaliteit te hebben. Dit is tevens het geval als er geen extra restricties worden toegepast, naast de algemeen geldende restricties op de hoeveelheid bemesting en de tijd van het jaar waarin bemest mag worden.

De analyse van de methodologische vraagstukken heeft tot de volgende resultaten geleid. Verschillende manieren van categoriseren van de gegevens hebben inderdaad effect op de resultaten, met name op de voorspellende waarde van de gegevens. De verschillende classificatiemethoden resulteren echter niet in tegenstrijdige interpretaties van de uitkomsten. Bovendien kan worden geconcludeerd dat de categorisering van gegevens tot op zekere hoogte tot verlies van informatie leidt, maar in een mate die afhankelijk is van de classificatiemethode.

De analyse in Hoofdstuk 7 is gericht op de EU-landbouw/milieuverordening 2078/92, die in 1992 als begeleidende maatregel bij de MacSharry-hervormingen werd ingevoerd. Een belangrijke doelstelling van deze maatregel is het stimuleren van de positieve en het terugdringen van de negatieve, externe effecten van agrarisch grondgebruik. De landbouw/milieuverordening is de voorloper van het huidige plattelandsontwikkelingsprogramma (EU-verordening 1257/99). De individuele lidstaten zijn wettelijk verplicht om programma's in het kader van de landbouw/milieuverordening aan te bieden. De deelname van boeren is echter vrijwillig. De analyse in dit hoofdstuk is gebaseerd op case studies uit verschillende Europese landen, die het gedrag van boeren die aan landbouw/milieuprogramma's deelnemen, vergelijken met het gedrag van boeren die er niet aan deelnemen. De deelnemende boeren vormen dus de zogenaamde experimentele groep en de niet-deelnemende boeren vormen de controlegroep. Het gedrag van de boeren wordt met behulp van drie indicatoren gemeten: het verbruik van kunstmest, de gehanteerde veedichtheid en het aandeel grasland van het bedrijf. De indicatoren geven een maatstaf voor de gedragsveranderingen over een periode van vijf jaar (1993-1997).

Door het gebruik van een experimentele en een controlegroep in de case studies kunnen 'conventionele' meta-analytische technieken worden toegepast. Deze worden veelal in de medische wetenschappen gebruikt. Deze technieken zijn: het gebruik van 'standardised mean differences' als de effectindicator, het combineren van effectindicatoren en het toepassen van een moderator analyse. De effectindicator geeft aan of de gedragsveranderingen van de experimentele groep significant groter of kleiner zijn dan die van de controlegroep. In de moderator analyse wordt nagegaan of bepaalde variabelen invloed hebben op de omvang van de effectindicator. De toegepaste moderator variabelen zijn de gemiddelde compensatiebetaling per hectare, de gemiddelde bedrijfsgrootte, de gemiddelde absolute waarde van de indicatoren in 1997 en het type bedrijf (intensief of extensief, veeteelt of akkerbouw).

Inhoudelijk gezien kunnen op basis van de analyse in dit hoofdstuk de belangrijkste conclusies als volgt worden samengevat. Over het algemeen wijzen de resultaten erop dat de landbouw/milieuprogramma's tot positieve gedragsveranderingen bij de deelnemende boeren geleid hebben. Een interessant resultaat met betrekking tot het gebruik van kunstmest is dat hogere compensatiebetalingen niet noodzakelijkerwijs gekoppeld zijn aan een lager kunstmestverbruik. Het kunstmestgebruik is ook bij lagere compensatiebetalingen laag. Boeren die in het kader van de landbouw/milieuprogramma's gestimuleerd en geadviseerd worden, lijken zich dus te realiseren dat terugdringing (optimalisatie) van kunstmestgebruik voordelig is, ook zonder extra compensatiebetalingen. Met betrekking tot de methodologie is een interessant resultaat gevonden. Door het begrensde aantal observaties in de individuele case studies is een groot deel van de resultaten uit de case studies niet significant. De meta-analyse in dit hoofdstuk voegt deze resultaten samen en produceert op die manier een effect, dat aanzienlijk meer statistische waarde heeft dan de individuele resultaten uit de case studies.

Hoofdstuk 8 belicht de effecten van het agrarische inkomen op de waarde van landbouwgrond. De waarde van grond wordt bepaald door de verwachte rendementen van de grond in de toekomst. Vanuit theoretisch oogpunt leidt een markt- en inkomensstabiliserend beleid tot een hogere waarde van grond, omdat het optimistische verwachtingen over rendementen in de toekomst creëert. Er wordt aangenomen dat een hogere grondwaarde tot hogere kapitaalkosten leidt. Dit stimuleert wederom de intensieve productie, omdat deze kosten moeten worden terugverdiend. Bovendien reduceert een hoge grondwaarde de mobiliteit op de grondmarkt, hetgeen de re-allocatie tot minder intensieve gebruiksvormen van grond bemoeilijkt.

In de literatuur zijn veel studies te vinden die de omvang van het effect van het agrarisch inkomen op de waarde van grond schatten. De omvang van het effect wordt veelal weergegeven in de vorm van elasticiteiten met de procentuele verandering van de waarde van grond in de teller en de procentuele verandering van het inkomen in de noemer. In dit hoofdstuk wordt een meta-regressie uitgevoerd die gebaseerd is op 19 van dit soort studies met in totaal 218 waarnemingen in de vorm van elasticiteiten.

De studies in de meta-dataset hebben een aantal verschillende karakteristieken die verantwoordelijk zijn voor de uiteenlopende waardes van de elasticiteiten in de studies. De studies kunnen bijvoorbeeld verschillen in: geografische gebieden, tijdsperioden, landbouwgewassen, theoretische veronderstellingen, structuur van de data of econometrische schattingsmethoden. Een apart te noemen punt waarin de studies zich van elkaar onderscheiden, is de manier waarop het agrarisch inkomen wordt bepaald. Sommige studies gebruiken het netto-bedrijfsinkomen of opbrengsten uit marktgerichte productie als indicator. Andere studies hanteren de directe overheidssteun als indicator. Er wordt van uitgegaan dat de verschillende indicatoren verschillende vormen van beleid weerspiegelen. Studies die bijvoorbeeld opbrengsten uit marktgerichte productie als indicator hanteren, reflecteren voornamelijk het beleidsinstrument van de prijssteun, terwijl de indicator directe overheidssteun voornamelijk het instrument van de directe inkomenssteun reflecteert. Een vraag die met behulp van de meta-regressieanalyse beantwoord kan worden, is welke karakteristieken voor de uiteenlopende waardes van de elasticiteiten verantwoordelijk zijn. Met het oog op de hervorming van het landbouwbeleid is het vooral interessant om te kijken naar de effecten van de verschillende vormen van agrarisch inkomen zoals die in de studies worden gehanteerd.

Met betrekking tot het beleid kunnen de resultaten van de meta-regressieanalyse als volgt worden samengevat. Inkomen in de vorm van directe inkomenssteun van de overheid, lijkt een groter effect op de waarde van grond te hebben dan het inkomen dat in de markt verdiend wordt en dat voornamelijk de prijssteuncomponent bevat. Het is wel belangrijk om te vermelden dat de gebruikte studies uit een tijdsperiode stammen waarin directe inkomenssteun veelal gekoppeld was aan landbouwgrond. Bij een hervorming van het landbouwbeleid die gericht is op het overschakelen van prijs- naar inkomenssteun, is het dus belangrijk om de inkomenssteun van de landbouwgrond te ontkoppelen, indien men de inflatie van de agrarische grondprijzen terug wil dringen.

Naast de inhoudelijke discussie, komt tevens nog een belangrijk methodologisch vraagstuk aan de orde. Er wordt gekeken naar de afhankelijkheid tussen waarnemingen als gevolg van het gebruik van meerdere waarnemingen uit één studie. Dit vraagstuk is met behulp van technieken uit de ruimtelijke statistiek en econometrie geanalyseerd, omdat de afhankelijkheid tussen de waarnemingen in de meta-dataset te vergelijken is met de multi-dimensionale afhankelijkheid tussen waarnemingen in een ruimtelijke context. Een belangrijk resultaat dat uit deze analyse naar voren komt, is dat een precieze specificatie van het meta-model waarin met zoveel mogelijke individuele studiekarakteristieken rekening is gehouden, een groot deel van het probleem van de afhankelijkheid tussen de waarnemingen weg kan nemen.

Conclusies

Methoden van kwantitatieve onderzoekssynthese kunnen waardevolle inzichten opleveren in het kader van de analyse van landbouw- en milieubeleid. De effecten van landbouw- en milieubeleid zijn vaak afhankelijk van de omstandigheden in een bepaald gebied of regio. Met behulp van de kwantitatieve onderzoekssynthese kunnen case studies, die in verschillende gebieden of regio's uitgevoerd zijn, samengevat en geanalyseerd worden. De karakteristieken van de case studies, die onder anderen de specifieke omstandigheden van het studiegebied reflecteren, kunnen als verklarende variabelen voor de variatie van de beleidseffecten opgenomen worden in de analyse. Op deze manier kan inzicht verkregen worden in de factoren, die het succes of het falen bepalen van bepaalde vormen van beleid in bepaalde gebieden. Op grond daarvan kunnen mogelijk aanbevelingen voor gebiedsgericht beleid gedaan worden.

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