

Economic Analysis of Dutch Agricultural Land Use
in a Changing Policy Environment

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Thesis

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1.1 Policy influences on farmland conversion

The Dutch land based agricultural sector is in transition. The Netherlands has a world-wide leading position in agriculture; however, even though production is still increasing, its relative economic national importance is declining, from 3.2% of GDP in 1995 to 1.6% of GDP in 2012 (LEI, 2014a). So is its uptake in land, although at a slower pace (CBS, 2014). Agricultural land in the Netherlands still accounts for more than two-thirds of all land (LEI, 2014b). However, land not only shifts in use between the agricultural and other sectors, but also within the agricultural sector. Farmland conversion is shaped by various driving factors, two of which are policies: the European Union's Common Agricultural Policy (CAP) and spatial policies.

1.1.1 *The CAP and its reforms*

Ensuring an adequate food supply was seen as a key task for governments in Europe after 1945, due to the food shortages experienced during World War II and the need to modernize the economy. Each country followed its own agricultural policy until the emergence of the Common Market in the 1950s led to the CAP, decided upon by the Treaty of Rome. By 1962, three major principles had been established to guide the CAP: 'market unity' (meaning common agricultural prices), 'community preference' (preference for own products) and 'financial solidarity' (joint financial responsibility). The common goal of the CAP was thus based on the idea of food security and free trade on a European scale, while ensuring a reasonable income for farmers. In order to achieve these twin aims, a number of common market-control regulations were introduced: tariffs on food imports and export subsidies to protect the internal market and to keep internal market prices high and stable.

Over the following decades, a gradual shift in the position and implementation of the CAP took place. The imbalance between internal and world market prices led to high public costs and tensions with countries outside Europe, notably in the negotiations of the General Agreement on Tariffs and Trade (GATT), later the World Trade Organization (WTO). Modernization of the economy led to a decreased importance of the agricultural sector in terms of employment, GDP and consumer spending on food and agricultural products. This changed the public view on the necessity of government-induced price stabilisation. Society started to notice the negative consequences of the CAP in terms government spending and wanted more attention for the positive and negative external effects of agriculture, e.g. nature conservation and animal welfare. The enlargement of the EU with member states with a relatively large agricultural sector would further increase budget expenditures, likely complicating future CAP reforms (Meester, 2005). Together, this led to several rounds of reforms aiming to control supply and eventually replace price support by direct income payments, with an increasing focus on sustainable agricultural production (Silvis and Lappere, 2010).

Overproduction and the negotiations of the Uruguay Round of the GATT were the main driving forces leading to the MacSharry reform in 1992. This reform laid the foundation for the transition from market and price (support) policy to a direct income payment system. Products receiving price support, such as cereals, oilseeds, tobacco, milk, beef and lamb, saw a reduction in their degree of protection. In return, producers started receiving direct payments. This transition was restated by the reforms that followed: Agenda 2000, the Mid-Term Review (Fischler reform), the Health Check and more recently the 2013 CAP reform. Agenda 2000, mainly motivated by the WTO's Doha Round and the enlargement of the EU, further reduced price support and introduced cross-compliance measures. Farmers had to comply with standards for 'good agricultural and environmental practice', allowing member states to provide or withhold payments depending on producers' compliance. The Mid-Term

Review of June 2003 contained a more incisive move towards direct payments. Moreover, further attention was paid to sustainable production, mainly through compulsory cross-compliance measures, meaning that land receiving payments should be kept in good agricultural condition (Silvis and Lappere, 2010). Now that price and income support was converted to direct payments, overproduction was no longer an issue. The reduced need for production limitations led to the 2008 Health Check's decision that production restrictions for milk and sugar could be gradually eased, to be eventually abolished. The 2013 CAP-reform was the most recent step in the transition towards decoupling.

1.1.2 Spatial policies in the Netherlands

All land-based sectors (e.g. residential, nature or agricultural land) exercise a claim on land. Spatial policies aim to regulate land use in an efficient manner, taking into account the external effects of land use, thereby determining the allocation of different types of land. These policies help concentrate urban areas and maintain open spaces around them. This leads to sectors with lower marginal returns to be allocated to areas that, without these policies, would have been occupied with activities with a higher shadow price (profitability) of land. This especially accounts for agricultural land, which is commonly understood as having a lower shadow price compared with residential areas. However, agricultural land may have larger positive externalities compared with residential areas, such as biodiversity gains or benefits to landscape (e.g. open space) and recreation values (OECD, 2009). The most common way to regulate land use is by exercising zoning laws. Zoning laws restrict the location and type of land use in a certain area by posing rules and regulations on the use per parcel of land. This is especially an effective policy in areas that are under influence of urban pressure. In the Netherlands, all (agricultural) land is zoned (IENM, 2011). Within the agricultural zones restrictions can apply with regards to the location and size of e.g. barns. Many countries apply spatial policies by imposing rules that directly influence the use of land. In this dissertation, I

limit the focus to the Netherlands where comprehensive spatial planning has been developed since 1945 (Faludi, 1991). After an initial focus on resolving housing shortage, the First White Paper on Spatial Planning (*Eerste Nota Ruimtelijke Ordening*) of 1960 served as a major landmark in the formation of the spatial agenda. The Spatial Planning Act (*Wet op de Ruimtelijke Ordening, WRO*), first enacted in 1965, administers spatial and urban planning. This can be subdivided between three governmental bodies: the national government that unfolds the key plans, according to which provinces position their regional plans which are translated into structural plans by municipalities. The new WRO of 2006 gave more authority to the municipal government which can now use national and provincial regulation as internal guidelines rather than seeking prior approval. The latest spatial policy is outlined in the 2013 Structural Vision (*Structuurvisie Infrastructuur en Ruimte*).

Spatial planning in the Netherlands consists of five key principles: concentration of urbanization, spatial cohesion, spatial diversity, hierarchy and spatial justice. All of these are, albeit to various extents, of influence to the location of agriculture. Concentration of urbanization, spatial cohesion and spatial differentiation all work via the Spatial Planning Act and aim to manifest cities and to keep them compact and well connected. This leaves more room for open-space concepts around cities such as for agriculture and nature areas. Spatial hierarchy and spatial justice locate and distribute economic activities according to their importance, with rural development considered as a target area. The importance of agriculture in spatial planning policies has however been declining. As a result of increased globalization and productivity growth, as well as the market liberalization of the CAP reforms outlined above, less agricultural land is considered necessary for production in the Netherlands (Hajer and Zonneveld, 2000). The decreased importance of agricultural land has mainly shifted towards nature areas. According to the 1994 Green Space Structure Plan 169,000 ha of agricultural land were planned to be converted to nature areas (LNV, 1994). In 2000, this was topped by almost 50,000 ha. However, the actual conversion of land has been

far lower (Lauw *et al.*, 2003). Agriculture is now considered to be the most important provider of land use change, both towards residential and nature areas. However, at a decreasing speed of conversion over time (Koomen *et al.*, 2008).

1.1.3 *Farmland conversion in the Netherlands*

Rising pressure on agriculture due to its decreased importance in spatial policies has led to an increasing amount of competing claims on land, and consequently a slow decline in agricultural land of, on average, 4% per decade (OECD, 2009). In the Netherlands, a country with a long history of agricultural export, this decline has been more profound. Until 1967 there was a continuous increase in the total amount of agricultural land due to land reclamation. Since then, however, agricultural land has declined, with about 0.4% or 8,000 hectares per year, totalling around 1.9 million hectares of agricultural land in 2012 (see figure 1.1). Around two-thirds of the decline in agricultural land went to increasing urbanization and one-third to nature development. The fact that the decline in agricultural land has not happened at a faster pace can be partially explained by spatial policies. Since the 1980s, there has been increased concern, especially for land-based sectors, to lose large parts of agricultural land to other functions due to, amongst others, a rising productivity of land and increased competition with countries with cheap land and labour available compared with the Netherlands (Agricola and Vereijken, 2004). However, empirical evidence shows that the high costs for land and labour in the Netherlands are largely compensated by the high productivity per unit land and labour. There is a trend towards fewer, but larger farms; land of farms that shrink or discontinue their agricultural operations is often bought by other farmers, as can be seen by the declining number and rising average size of farms in figure 1.1.

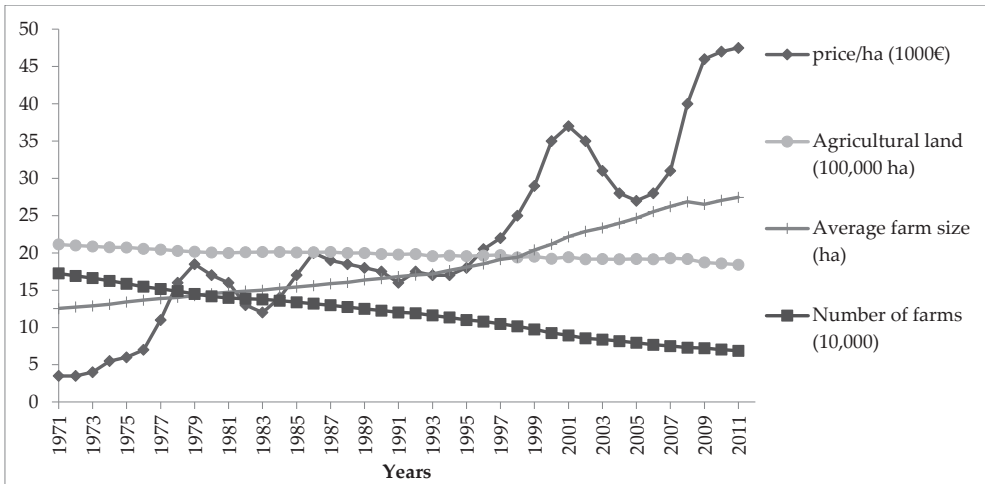


Figure 1.1 Development of agricultural price, land, farm size and number of farms between 1971-2011.

Land conversion within the agricultural sector is largely dependent on the time-horizon of decision making. If a farmer's planning horizon is short, adjustments can only be made if there are no large fixed capital investments involved (OECD, 2009). Indication for this can be found in figure 1.2, where alterations in total hectares of land are much larger within arable crops because that only requires small on-farm adjustments (cereals, sugar beet, potatoes, onions, grassland fodder maize) compared with adjustments between the arable and livestock sectors. Here, adjustments in fixed capital and therefore long time periods are required for the shift to pay off.

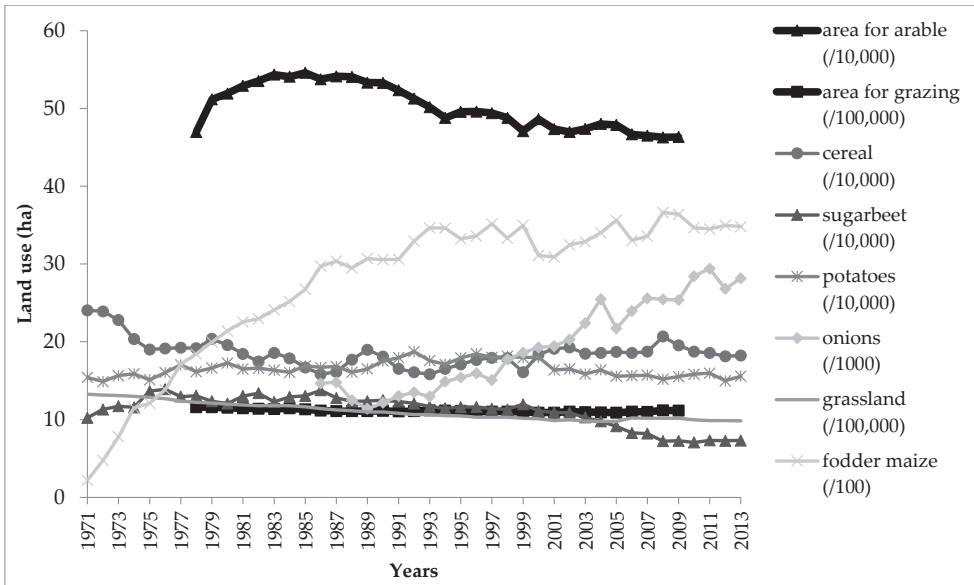


Figure 1.2 Changes in hectares of land per land use and for arable and grazing farms between 1971-2013.

Agriculture is essentially a spatial activity. The OECD (2009) distinguishes three types of agricultural area: land at the urban fringe, the agricultural zone and the extensive margin. Pressure for farmland conversion is at its highest in the urban fringe and the extensive margin. The Netherlands is highly urbanized, and therefore most agricultural land is considered to be located in the urban fringe; the area where transition between agriculture and residential areas takes place. Within the agricultural sector, activities in the Netherlands still largely follow the conventional model of Von Thünen with high-value agriculture using large transportation costs, such as greenhouse farming, located in urban areas and low-value agriculture, such as arable farming, located in the relatively rural areas. Strong zoning policies distinguish agriculture in the urbanized West into two types: greenhouse farming and land-based farming, mainly dairy farming (Alterman, 1997). These two types differ in terms of profits and

externalities: dairy farming has large positive externalities in terms of landscape but relatively low returns per hectare, whereas greenhouse farming has low positive externalities but high returns per hectare. Another main geographical differentiation in land-based agriculture is that between arable farming and grazing livestock (mainly dairy farming), with arable farming mostly located in the South-West and North-East (provinces of Zeeland, Flevoland and Groningen) and dairy farming mostly located in the North-West and Mid-East (provinces of Friesland, Utrecht, Gelderland, Overijssel, and Friesland) (see figure 1.3). However, with dairy farmers increasingly buying land of arable farmers, this geographical differentiation has declined in importance.

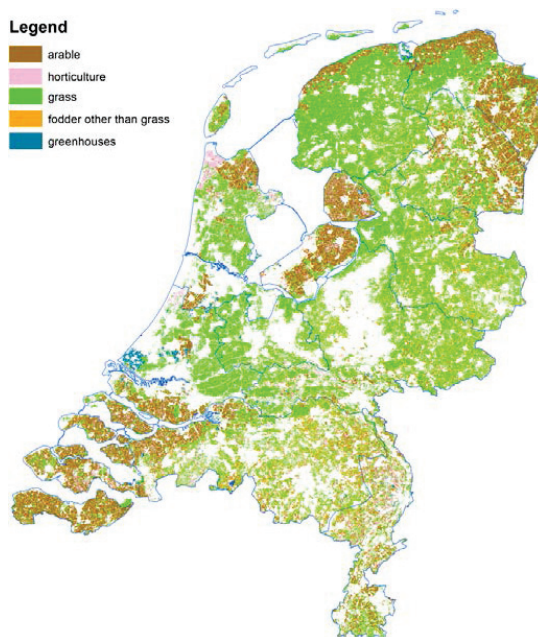


Figure 1.3 Agricultural land use in the Netherlands in 2013 (LEI, 2014c).

1.2 Driving factors of land use and price changes

The spatial planning (zoning) policies and the CAP have led to a more secure position of land-based agriculture in the allocation of land. However, policy changes, especially the CAP reform, lead to more risk and uncertainty, affecting producers' decision-making and consequently their land use. Naturally, there are many driving factors of land use change and analysing all of them would go beyond the scope of this thesis. However, the elements CAP reform, risk and uncertainty and agricultural land use (change) led to the selection of the following four factors: increased price volatility and resulting uncertainty, production limitations, direct payments and the need for risk management. These factors influence the shadow price (i.e. profitability) of agricultural land for individual sectors and therefore induce land-use changes.

1.2.1 *Increased price volatility and resulting uncertainty*

The EU's reduced intervention in agricultural markets has led to increasingly volatile output prices and more income uncertainty (Havlik *et al.*, 2005; Hennessy, 1998). Uncertainty about output prices differs per activity and over time. Land-based activities such as dairy and arable farming are less volatile than non-land based sectors such as poultry or greenhouse farming (LEI, 2014d). However, for an individual producer, increased output price volatility does not necessarily imply changes in the level and variance of income, because income also depends on input costs and yields, and the correlation between them (Pennings *et al.*, 2010). More specifically, a producer faces different kinds of uncertainty: production uncertainty, due to uncontrollable elements such as weather; price uncertainty, because the output price is unknown at the time decisions have to be made; technological uncertainty; and policy uncertainty (Moschini and Hennessy, 2001). Depending on the correlation between different kinds of uncertainty, the increased price volatility may result in more overall uncertainty for producers. The resulting uncertainty in producers' incomes leads to rising income risk

(Hardaker *et al.*, 1997). However, the increased risk perceived does not only depend on current activities, but is also relative to other activities. In selecting potential alternative land uses, it may be of importance whether these land uses are substitutes or complements compared with current land-use activities. Hence, the likelihood for land-use change depends on the degree to which the producer is risk-averse and on whether the crops are complements or substitutes.

1.2.2 Production Limitations

Due to the price and income support overproduction occurred for certain products. One of the most well-known are dairy products, where measures such as subsidies for livestock sales, slaughter premiums and price reductions could not prevent large overproduction. This led to the introduction of milk quotas in 1984. The total quota amount in the EU was secured at the 1981 level (+1%), while the distribution was country-specific. If a farmer produced more than his quota amount, he had to pay a 'super levy', initially set at 115% of a target price. With the transition from price support towards decoupled direct income support, quota remained binding in only a few countries. This implied that only for these countries, among others the Netherlands, national production was restricted to the level set by the quota. The fact that the difference between EU and world market prices had disappeared led to the decision to expand, and eventually abolish, the milk quotas. The 2003 Fischler reform and 2008 Health check contained several quota increases until eventual abolition takes place in 2015.

Like the introduction, the abolition of milk quota is expected to affect farms. When milk quotas are no longer present, land is likely the scarcest production factor in dairy farming in the Netherlands, thereby determining the level of dairy production. Although the impact of milk quotas is complex, they are likely to hamper changes on dairy farms (Piet *et al.*, 2012). Existing research on the influence of milk quotas includes the impact on changes in farm size (Breustedt and Glauben, 2007; Huettel and Jongeneel, 2011; Zimmermann and Heckelei, 2012), production (Ooms and Peerlings, 2005; Breustedt and Glauben, 2007; Huettel and Jongeneel,

2011) and farm characteristics (Gale, 2003; Ooms and Peerlings, 2005; Huettel and Jongeneel, 2011). However, the impact on land or the time at which land-use changes occur has not been addressed. In light of the assumed transition from milk quotas to land as the scarcest production factor, it is of importance to analyse the dynamics of land-use change in dairy farming.

1.2.3 Land prices

So far, a surplus of agricultural land has not occurred in the Netherlands. This is mainly because the land of producers who exit farming is bought by other producers. The real price of agricultural land has remained stable between the late '70s and mid '90s, after which a fluctuating but steep rise in prices followed (DLG, 2014; LEI, 2013). The increase in farmland prices goes hand in hand with an increase in farm size for land-based agriculture (see figure 1.1). To a certain extent, this provides an explanation for the rise in land prices: increased farm size, caused by increasing returns to scale, leads to a larger Net Present Value (NPV) of the shadow price of land. However, the fluctuations and rapid rise in the price of agricultural land over the past two decades cannot be explained by changes in the NPV alone: several other factors help explain the price of agricultural land. A widely researched example is the capitalization of direct payments in the price of agricultural land (Clark *et al.*, 1993; Goodwin *et al.*, 2003; Latruffe and Le Mouël, 2009). However, also non-income generating factors are of importance, such as location characteristics (Shi *et al.*, 1997; Livanis *et al.*, 2006), price cycles (LEI, 2013), macro-economic and demographic variables (Devadoss and Manchu, 2007), land-use and institutional and transaction regulations (Ay and Latruffe, 2013; Just and Miranowski, 1993). Together, these factors try to explain the 'farmland valuation puzzle' (Power and Turvey, 2010).

1.2.4 Direct Payments

Direct payments can be seen as the embodiment of the move away from support measures for specific products towards a less market-distorting system where agricultural subsidies are paid directly to farmers, conditional upon certain practices but decoupled from production. This system was gradually introduced between January 2005 and January 2007 under the name Single Payment Scheme (SPS). While the European Commission expressed a preference for regional area-based payments, countries could choose between a historical, regional or hybrid model (Matthews *et al.*, 2013). The majority of countries opted for the historic model, where entitlements depend on farm-specific historical reference amounts.

One would expect that, when subsidies are completely decoupled from production, the level of output with subsidies should equal that without subsidies. Hennessy (1998) found that impacts of these income-support programs can be divided into a wealth, insurance and coupling effect. Decoupled payments add a stable part to the producer's income, removing part of the uncertainty about the level and variance of income, thus leading producers to optimize their portfolio of activities to one closer to a risk-neutral situation. Chavas and Holt (1990) found indication of this wealth effect by estimating risk preferences together with production-function parameters. The effects of decoupling have been extensively researched. These include impacts on investment decisions (Sckokai and Moro, 2009), changes in labour allocations (Key and Roberts, 2009; Hennessy and Thorne, 2005), increased land and rental prices (Brady *et al.*, 2009), and the competition for land within the agricultural sector (Gohin, 2006). Except for the effect of decoupled payments on land prices, various studies found limited impacts of decoupled payments on farm operations (see Bhaskar and Behin, 2009 for an overview). However, this may also be due to the different ways decoupling was implemented among different member states.

The CAP reform of 2013 entails a gradual implementation of the regional model where the same level of support applies to every hectare of agricultural land, independent of the crops

cultivated (i.e. flat rate). In addition, producers are compensated for providing public goods in the form of environment-friendly farming practices – a so-called greening component that is added to the new SFP if farmers are in compliance (European Commission, 2014a). For countries which used to have the historical model, such as the Netherlands, this implies a move from coupled support to support decoupled from crop yield but not crop allocation and, finally, to support decoupled from choice of crop activities but with more emphasis on environment-friendly practices (Helming *et al.*, 2010). Therefore, the effects on land use of a transition towards a flat-rate payment according to the 2013 CAP reform might be more significant than the introduction of the SPS under the Mid-Term Review.

1.2.5 *The need for risk management*

Producers are generally considered to be risk averse, meaning they will give up some level of expected income in order to reduce the possibility of a negative outcome (Arrow, 1996). The most common way for them to do so is by altering their production plan. This is why, upon analysing land allocation decisions, producers' preferences have often been characterized using an expected utility function (Chavas and Pope, 1985; Coyle, 1999; Oude Lansink, 1999; Sckokai and Moro, 2006). Although there has been quite some critique on the approach of an expected utility function (see e.g. Buschena and Zilberman, 1994), it is still one of the leading frameworks to describe producers' economic choices.

The increased instability of agricultural incomes strengthens the need for risk management. Risk management is used to control the possible adverse consequences of uncertainty that may arise from production decisions. A producer may adopt several measures to decrease rising income risk, such as crop diversification, forward and future contracts. Government policies are also aimed at reducing production risk. To shift risk away from producers, government intervention is necessary, due to failures in the ideal competitive market for risk-shifting (Arrow, 1996). This is especially the case for catastrophic events, such as floods and

droughts, which are characterised by systemic risk, meaning that there is a large geographical correlation between farms (Meuwissen *et al.*, 2003; Glauber, 2004; Miranda and Glauber, 1997). A well-known measure supported by governments to provide assistance in risk management is the possibility for farmers to insure (part of the) farm operations. These may protect against the risk of losing (part of the) income due to catastrophic events (such as livestock diseases) or common fluctuations (such as whole-farm insurance). Programs reducing income variability entail both a wealth and an insurance effect that may lead to different land allocation decisions (Hennessy, 1998; Chavas and Holt, 1996; Adams *et al.*, 2001). The recent spikes in agricultural prices caused an increased appeal for financial safety nets among member states. Although eventually not adopted, the proposals of the 2013 CAP reform entailed a risk management toolkit, including whole-farm income insurance.

1.3 Objective and research questions

The location and use of agricultural land in the Netherlands is partly due to two protective policies: zoning policies and the CAP. Changes in these policies influence both the use and the price of agricultural land. At the changing interplay between the CAP and spatial policies this study aims to investigate driving forces of agricultural land use and price changes in the Netherlands. For this purpose the following objective is defined:

“To investigate farmer’s decision-making on agricultural land use changes in the Netherlands, accounting for the role of the EU’s CAP reform”.

Five driving factors influencing decision making on both on-farm land adjustments and changes to the size of the farm are selected: increased price volatility and resulting uncertainty, production limitations, land prices, direct payments and the need for risk

management. From the main objective the following five research questions are defined and worked out in subsequent chapters:

1. What is the effect of volatile agricultural output prices on agricultural land use over the past decade?
2. What is the effect of the abolition of milk quota on the time period between agricultural land-use changes?
3. How can farmland prices, and more specifically the effect of the financial crisis on the land market price, be explained?
4. What is the effect of the transition from a historic-reference payment to a single (per ha) farm payment, including a green payment (GP) option, on the way the farmer allocates his land to various crop activities?
5. What is the effect of insurance possibilities, more specifically crop-specific and whole farm insurance, on agricultural land use?

1.4 Data and models

Driving factors of land use change impact different types of farms in various ways. In order to study the socio-economic drivers of land use change, models and data are required that explicitly take individual producers' behaviour into account.

This study utilises three different datasets, all describing factors relating to land use of land-based farms in the Netherlands. The Farm Structure Survey (FSS) considers production activities of all farms in the Netherlands from 1971 onwards. It contains the amount of land and its allocation and a limited number of production factors (e.g. livestock, labour) and farm characteristics (e.g. age of the farmer). A more detailed account of on-farm production can be found in the Dutch Farm Accountancy Data Network (FADN). This dataset is available from 2000 onwards and contains economic details on farm production activities for a representative sample of farms. The third dataset is LEI's land transaction database which is based on

cadastral data, considering all transactions to and from farmers between 1998 and 2011. Besides the price and number of hectares transacted, it contains information on the parcel of land transacted and the buying/selling farmer. Depending on the research question, the most suitable methodology and (combination of) data is chosen.

To analyse the aforementioned research questions, several quantitative methods are employed that take systematic differences between farms into account. Panel-data econometrics, using historic data, explain land use changes using various explanatory variables. Land-use models based on mathematical programming enable to make statements on hypothetical land-use changes, mainly because constraints and policy instruments can be added and no large amount of data is required. Spatial econometric techniques further help assess the influence of location.

1.4.1 Volatile output prices

The EU's CAP reforms to liberalize markets and decouple payments from production have thus led to increasingly volatile output prices, and therefore more price and income risk. There is an extensive amount of literature on the estimation of models that analyse the influence of output price volatility on agricultural land allocation decisions. Broadly, two lines of thinking can be distinguished: estimating a system of output supply, input demand, and land-use equations (Coyle, 1992; Oude Lansink, 1999; Sckokai and Moro, 2006), and estimating land-use response equations (Moore and Negri, 1992; Wu and Segerson, 1995; Fezzi and Bateman, 2011). The two approaches were integrated by Chambers and Just (1989) and extended by Arnade and Kelch (2007) and Fezzi and Bateman (2011). Estimating land-use response equations that account for the effect of price uncertainty on alternative land uses has not yet been undertaken. To assess the income and risk effects of volatile output prices on agricultural land-use I therefore estimate a multiple-equation panel data model. The land-response equations are based on a restricted profit function, taking both risk and farm technology into

account. Data from the FSS on 66 Dutch agricultural regions from 2000 through 2013 is used to analyse the land-use decisions of producers.

1.4.2 *Milk quota*

The uncertainty regarding the abolition of production limitations impacts the dynamics of producers' decision-making. Most studies analysing the impact of quota abolition focus on the magnitude of change in certain factors, but not on the timing of changes. Here, the analysis comprises the time period between two changes in land used for milk production on dairy farms and the direction of change, either positive or negative, before, during and towards the abolition of milk quota. In the FSS, all farms remain in the sample until they decide to exit farming or continue farming under a different name (e.g. in case of a merger). Because of this latter possibility, it is not possible to study farm entry and exit decisions. It is however possible to study growth, both in its positive and negative meaning. A dataset from the FSS comprising farm-level data of the Netherlands between 1971 and 2011 is used to estimate two duration models, analysing the time period between increases and decreases in dairy land use.

1.4.3 *Land prices*

Farmland prices can only to a limited extent be explained by the discounted shadow prices of land (NPV), where the NPV is usually comprised of the average stream of discounted net revenues and direct payments (see Latruffe and Le Mouel, 2009, for an overview of studies using the NPV approach). Previous studies have noted that the purchase and rental prices of farmland may entail spatial effects that need to be further explained (Patton and McErlean, 2002; Breustedt and Habermann, 2011; Guastella *et al.*, 2013). In order to better assess how farmland prices are composed, it is of importance to distinguish the part explained by revenues directly obtained from farming from all other factors explaining farmland prices. In this chapter, three categories influencing the price of land are used besides those factors that

directly influence the returns from land; institutional regulations, the spatial environment and local market conditions. Using the land transactions database covering the period between 2004 and 2011, all transactions where the purchaser practices land-based agriculture are selected. These are divided in two equal periods to distinguish the effect of the crisis on the agricultural land market.

1.4.4 *Direct payments*

For the Netherlands, the flat-rate payment may lead to a lower level of income support and an increase in income uncertainty. Thus, it is prudent to investigate if, and under what circumstances, this implies land-use changes, and more specifically the adoption of greening practices, for farms of different sizes. This chapter analyses the effect that the different payment mechanisms, including both SFP and green payments (GP), have on land use (crop allocation) decisions. In essence, the effects of the 2003 Mid-Term Review is compared with the single-farm payment of the 2013 CAP reforms on cropping decisions using the Netherlands as a case study. Using FADN data for representative Dutch arable farms of different sizes, a farm-level crop allocation model is developed that is calibrated using positive mathematical programming.

1.4.5 *Insurance*

Insurance possibilities ultimately reduce risk in farmer's land-use decision-making. The methodologies used in the literature on the influence of insurance measures on production and land-use decisions can be divided into simultaneous equation models investigating acreage response of different types of insurance schemes (Goodwin *et al.*, 2004; Wu, 1999; Wu and Adams, 2001) and mathematical programming models that examine changes in a farmer's crop portfolio (Turvey, 2012). New agricultural policies might be better modelled using a mathematical programming framework (Heckeley *et al.*, 2012). In order to analyse the uptake

and impact of crop-specific and whole-farm insurance, a farm management model with the objective to maximize utility is developed, where insurance depends on crop allocation, while at the same time crop allocation depends on the type of insurance provided. Using the same FADN data for representative Dutch arable producers of different sizes, optimal crop portfolio changes are analysed as the insurance instrument changes. The model is calibrated using positive mathematical programming, and random revenue outcomes based on Monte Carlo simulation of crop prices and yields, thereby explicitly accounting for trends in prices and variability in prices and yields.

The outline of this thesis is as follows. Chapters 2 through 6 deal with the specific research questions 1 through 5 introduced above, respectively. The last chapter provides conclusions and a general discussion.

CHAPTER 2. EFFECT OF OUTPUT PRICE VOLATILITY ON AGRICULTURAL LAND USE¹

Abstract

The EU's CAP reform to liberalize markets and decouple payments from production has led to increasingly volatile output prices, and therefore, more price and income risk. In this study, eight land use share equations are specified and estimated using regional data from 2000 through 2013. A multiple-equation panel data model is used to determine the contribution of increased price volatility and risk to land-use change. More specifically, it is investigated how relative perceived risk affects land use change. We found opposite effects between complementing and substituting land uses, leading to competition within the dairy sector and within crop production.

¹ Paper by Esther Boere, Jack Peerlings, Stijn Reinhard, Tom Kuhlman and Wim Heijman, Forthcoming in *New Medit*

2.1 Introduction

Over the past decade in the Netherlands, volatile output prices have led to fluctuating profitability of agricultural land and may therefore have affected land-use decisions. For a producer, the shadow price of land represents the land's marginal contribution to profit. If a producer has no constraints on land use, profit maximization occurs at the point where shadow prices are equal among all alternative land uses. However, the equality of shadow prices among land uses only accounts for expected output prices because producers do not know output prices at the time they choose their production activities, and must base their expectation on past experience. This causes uncertainty for the producer about the difference between the actual and expected output price, which may differ per activity and through time. For a risk-neutral producer uncertainty will not influence his production decisions. For a risk-averse producer, production activities with a high expected output price and a low profit variability are preferred. A risk-averse producer, faced with increased volatility in output prices, is therefore more likely to switch to less volatile production activities.

The European Union's Common Agricultural Policy (CAP) is shifting away from market and price support to liberalized markets and decoupled payments from production. This is likely to result in an increased volatility of output prices and hence, farm profits, which affects the competitive positions of agricultural and non-agricultural land uses (Ridier and Jacquet, 2002; Sckokai and Moro, 2006; Brady *et al.*, 2009). However, because the degree of volatility is crop-specific, the effect on farm plans has so far remained unclear.

Competing agricultural and non-agricultural claims arise, especially in areas such as the Netherlands where land is scarce. In this chapter our focus is solely on agricultural land use, ignoring competition with other sectors and taking the total (decreasing) amount of agricultural land as given.

There is an extensive literature on the estimation of models that analyse multiple-output supply decisions and agricultural land allocation decisions. Broadly, two lines of thinking can

be distinguished: estimating a system of output supply, input demand, and land-use equations (Coyle, 1992; Oude Lansink, 1999; Sckokai and Moro, 2006), and estimating land-use response equations (Moore and Negri, 1992; Wu and Segerson, 1995; Fezzi and Bateman, 2011).

Estimating a system of output supply, input demand, and land-use equations has been applied by Coyle (1990; 1992; 1999), who combined the effects of risk aversion, price uncertainty, and yield uncertainty on crop production decisions in mean-variance duality models of production. Oude Lansink (1999) elaborated on Coyle's work by using a linear mean-variance utility function that incorporated risk to determine the input demand, output supply, and area allocation simultaneously among various crops. More recently, Sckokai and Moro (2006) adapted Coyle's framework to account for the increased output price volatility caused by CAP reforms in a study of crop production.

Estimating land-response equations has been applied by Moore and Negri (1992) to develop land and water allocation equations based on a flexible functional form of a multi-crop production function. Wu and Segerson (1995) elaborated on this model by adjusting it to account for land heterogeneity.

The two approaches were integrated by Chambers and Just (1989), who used a two-step modelling framework: this approach allocates land among different production activities after the optimal levels of outputs and inputs have been determined. Arnade and Kelch (2007) extended this framework by deriving shadow price equations for crop areas. Fezzi and Bateman (2011) used the Chambers and Just framework to establish a joint profit function to derive equations for "land-use share" (the proportion of the land area allocated to each use) that can be estimated as a system. There also exists a great body of literature on yield risk (Just and Pope, 1979; Chavas and Holt, 1990). However, in order to focus on price risk, we choose to ignore yield risk. Estimating land-use response equations that not only account for the effect

of price uncertainty on its own land use (e.g. price uncertainty of wheat on the land use of wheat), but also on alternative land uses (e.g. sugar beets) has not yet been undertaken.

The purpose of this chapter is to assess the effect of volatile agricultural output prices on changes in agricultural land use since 2000 in the Netherlands by estimating a system of land-response equations. The land-response equations are based on a restricted profit function, taking both risk and farm technology into account. We used data on 66 Dutch agricultural regions from 2000 through 2013 to analyse the land-use decisions of producers.

In the next section we establish land use share functions that account for the risks that result from increased price volatility. Moreover, we hypothesize that the effect of agricultural outputs being complements and substitutes affects land use decisions. Next, we describe the study area and data sources. We then develop an empirical model in which the producer optimizes his profit by allocating land among different uses while accounting for risk. In the final sections, we econometrically estimate the land-use share equations, discuss the results, provide a general discussion, and present the main conclusions drawn from our study.

2.2 Theoretical Framework

Building upon the work of amongst others Chavas and Pope (1982), Coyle (1990, 1992) and Wu and Segerson (1995) we derive a system of land use share equations based on a utility maximizing producer. We assume a profit function with multiple outputs (land uses or crops), where the producer must decide how to allocate his hectares among different land uses in order to maximize total profits (Wu and Segerson, 1995). The profit function is elaborated by accounting for risk in production decisions; the producer therefore becomes a utility-maximizer (Oude Lansink, 1999). Expected utility is determined by the expected profit, the variance of profit, and the coefficients of absolute risk aversion per crop (see e.g. Coyle, 1990, 1992). Based on utility maximization we derive land-use share functions that represent the proportion of the land that producer h allocates to land use i in year t :

$$s_{hit}^U = s_{hit}^U(\hat{\mathbf{p}}_t, \mathbf{w}_t, \mathbf{q}_{ht}, \mathbf{z}_{ht}, \mathbf{Vp}) = \frac{n_{hit}^U}{N_{ht}} \quad h=1, \dots, H; i=1, \dots, I; t=1, \dots, T. \quad (1)$$

The land-use share of producer h for crop i in year t (s_{hit}^U) depends on all expected output prices ($\hat{\mathbf{p}}_t$) and known variable input prices (\mathbf{w}_t) in year t , yields (\mathbf{q}_{ht}) of producer h in year t , fixed input quantities (\mathbf{z}_{ht}) of producer h in year t , the variance of prices (\mathbf{Vp}), and the degree of risk-aversion. The land use shares equal the number of hectares n_{hit}^U of producer h allocated to crop i in year t divided by the total number of hectares N_{ht} of producer h in year t . When $\mathbf{Vp}=0$, the land-use share equation for the utility-maximizing producer equals the land-use share equation for the profit-maximizing producer. For the mathematical derivation from the profit function to the land use shares, we refer the reader to the Appendix.

2.2.1 Ratio of coefficient of variations

Figure 2.1 shows that for all output prices there is some degree of volatility. We assume that, when determining optimal land use, the producer looks at the relative price volatility between crops; hence the variation of a crop compared with the variation of the alternative crops. To take this into account, we take the ratios of the coefficients of variation as elements of \mathbf{Vp} :

$$v_{ir} = \frac{\sigma_r / \mu_r}{\sigma_i / \mu_i} = \frac{Cv_r}{Cv_i} \quad i, r=1, \dots, I; i \neq r, \quad (2)$$

where Cv_r is the 3-year moving average of the coefficient of variation, the standard deviation divided by the average, of the output price of the alternative (substitute or complement) crop and Cv_i is the 3-year moving average of the coefficient of variation of the output price of the crop of interest. Hence, in 'the ratio of the coefficients of variation' the CV of the alternative crop is in the numerator and that of the crop of interest in the denominator.

We used coefficients of variation instead of variances because, in comparison to variance, the coefficient of variation is a unitized measure of risk. So, dividing the ratio of two coefficient of variations (see equation 2) does not lead to a violation of the homogeneity assumption.

2.2.2 *Substitutes and complements*

In the model presented, land use change depends on the factors determining the land shares, i.e. expected output prices, variable input prices, yields, quantities of fixed factors and the variance of output prices. Implicit is also farm technology relevant, showing to what extent the producer is able to adjust activities within his enterprise. One aspect of farm technology is whether production activities are complements or substitutes. Complements are defined as those activities that are in joint supply, either because of crop rotation requirements or because one output is needed as an input in producing another output. Substitutes are defined as (sets of) activities that are rival to each other.

For arable production in the Netherlands, the common rotation system is the joint production of cereals, potatoes and sugar beets. For dairy production, fodder maize and grassland can be viewed as complementary to milk production. When facing a larger expected utility, it is likely to be easier for a producer to switch activities within these two sets of production rather than between them.

Based on the ratios of coefficients of variation we can examine whether two land uses are substitutes or complements. For substitutes and in case of risk-aversion a producer will increase the share of a crop when the ratio of coefficients of variation increases (the coefficient of variation of the crop being in the denominator). For complements the opposite is true.

2.3 Data

We divided the Netherlands into 66 agricultural regions using an existing classification based on homogeneity of soil types (Helming, 2005; Helming and Reinhard, 2009). One of the advantages of using this classification for the types of agricultural regions is the relative homogeneity of the soil within these regions. All regions can be classified based on the soil type (clay, sand, or mixed soil that includes peats and loams). Different soil types generate different crop yields and therefore attract different production activities.

We aggregated farm structure survey (FSS) data for all farm households in the Netherlands from 2000 through 2013 into the 66 agricultural regions (Statistics Netherlands, 2013). Based on the available data, we defined eight agricultural outputs as the different types of land use. Specifically, we grouped the agricultural land uses into cereals, grassland, sugar beets, potatoes, fodder maize, onions, vegetables, and "other" (Table 2.1). In the Netherlands, grassland is mainly used for dairy production. Although beef and other cattle are also grazed in Dutch grassland areas, they account for a small proportion of the total grassland use. Moreover, nitrate regulations require a minimum amount of land per cow and thereby make dairy farming heavily dependent on the availability of grassland. Thus, in the rest of the chapter, we will refer to grassland exclusively in the context of dairy cattle.

For each year and each region, we calculated the amount of land (ha) for each land use using Dutch FSS data. We converted that area (ha) into land-use shares by dividing the area of each land use in a given region and year by the corresponding total amount of agricultural land. Table 2.2 summarizes the descriptive statistics for the agricultural land uses for the first and last years of the panel and for the panel as a whole. Table 2.3 summarizes the descriptive statistics for the explanatory variables.

The aggregation from individual crops to the eight land uses led us to use price indices instead of absolute prices for each land use. We first standardized all nominal absolute prices using

2000 as the base year before we normalized output prices by dividing them by the output price index of fertilizer (Eurostat, 2014; LEI, 2014c).

Table 2.1: Specification of land uses and their outputs

Land Use	Crops	Output price and yield
Cereals	Winter wheat, Summer wheat	Summer wheat
	Winter barley, Summer barley	
Grassland	Permanent grassland	Milk
	Temporary grassland	
Sugar beets	Sugar beets	Sugar beets
Potatoes	Seed potatoes,	Main crop potatoes
	Consumption potatoes	
Fodder maize	Fodder maize	Fodder maize
Onions	Seed onions, Seed onions	Seed onions
Vegetables	Endives, cauliflowers, leeks, broccoli, Brussels sprouts	Cauliflowers
Other	All other crops	Overall index

Unfortunately, it was not possible to retrieve all data on output and input prices from the same database. Therefore, data on absolute output prices for several land uses (cereals, grassland, potatoes, fodder maize, and onions) were retrieved from LEI (2014c), whereas data on absolute output prices for the other land uses (sugar beet, vegetables, and other) were retrieved from Eurostat (2014). Data on the input price of pesticides was retrieved from LEI (2014c), whereas data on the input price of fertilizer was retrieved from Eurostat (2014). We only include fertilizer and pesticides as variable inputs because all selected crops require these inputs.

For some land uses, we chose a proxy for output price (see Table 2.1). For onions, there was a limited amount of price data available. This led us to replace the output prices for onions from 2000 through 2004 with the corresponding prices from 1995 through 1999. The resulting

output price indices are shown in figure 2.1. As a measure of the expected output prices, we calculated an annual 3-year moving average (ending with the year previous from the year being studied) of the output prices.

Table 2.2: Summary statistics for agricultural land uses at the start and end of the period and whole panel.

Share ^{a)}	2000		2013		Whole panel					
	Absolute (1000 ha)	Share	Absolute (1000 ha)	Share	Mean	S.D.	Min.	Max	share non-zero obs	share left-censored obs
Cereals	183.64	0.10	182.37	0.10	0.10	0.11	0.00	0.41	0.99	0.00
Grassland	1010.02	0.52	982.95	0.54	0.53	0.27	0.09	0.99	1.00	0.00
Sugar beets	110.95	0.06	73.19	0.04	0.05	0.05	0.00	0.21	0.97	0.03
Potatoes	180.16	0.09	155.82	0.08	0.08	0.09	0.00	0.40	0.99	0.02
Fodder										
maize	205.30	0.09	229.74	0.11	0.10	0.08	0.00	0.40	1.00	0.00
Onions	19.27	0.01	28.17	0.01	0.01	0.02	0.00	0.12	0.84	0.22
Vegetables	6.44	0.00	6.70	0.00	0.00	0.01	0.00	0.06	0.93	0.08
Other	235.68	0.14	188.67	0.12	0.13	0.11	0.00	0.62	1.00	
Total	1951.45	1.00	1847.61	1.00	1.00					

^{a)} (absolute = the actual area; share = absolute area divided by the total area)

Producer expectations about price fluctuations are based on past experience. We assumed that price variation was equal across regions. The coefficient of variation of the normalized output price indices over the 3 years previous to the year being studied was used as a proxy for the expected variation in output prices. In addition to the output and input prices, we included the quantity of fixed inputs, yields and the presence of direct payments as explanatory variables. As a proxy for fixed inputs, we used the average size of a farm in a region, which was obtained from the FSS data. Size is measured by the standardized annual revenue of a specific production type per hectare of land or per animal. The average size was calculated as the sum of all farm sizes in a region, divided by the number of farms in the region and subsequently converted into an index. For each land use, the production (yield in kg/ha; Table

2.3) was converted into an index value similar to that for output prices (with the value in 2000 = 100). The presence of direct payments is referenced to as a dummy trend, starting in 2006 when direct payments were introduced, and taking the value zero prior to 2006.

The descriptive statistics in Table 2.2 show that average land use shares of the different agricultural land uses over all regions have changed only slightly over time. However, some land uses have changed considerably more than others. In particular, the area of sugar beets, potatoes and other decreased, whereas the area of grassland and fodder maize increased. This indicates a tendency towards dairy production. Grassland remained the main land use throughout the study period, with a share of more than 50% of the total agricultural land. The columns representing standard deviations, minimum and maximum shares of land use in Table 2.2 indicate large regional differences in land uses. This may be because of the division of regions based on homogeneity of soil. In varying degrees, almost all land uses are prevalent in each region during the whole period (see last column Table 2.2).

Compared to the relatively small changes in the land-use shares, figure 2.1 shows relatively large changes in output prices. The output prices seemed to follow some common trends in their fluctuations, such as decreases between 2003 and 2005 and between 2007 and 2008 and an increase over the last two years. However, large differences in the volatility of the output prices can be observed. Output price volatility was especially high for onions and potatoes, both in terms of the largest increase between two years (respectively 237.5 and 172.7 percent) and the largest decrease between two years (respectively -56.7 and -79 percent), compared to an average increase of 31.8 and an average decrease of 15.7 percent over all land uses between two years.

Table 2.3: Summary statistics of explanatory variables over the whole time period

Land-use	Mean	Std. Dev.	Min.	Max.
Expected output price indices (normalized by the price of fertilizer)				
Cereals	0.838	0.134	0.624	1.126
Grassland	0.770	0.182	0.493	1.159
Sugar beets	0.770	0.208	0.451	1.189
Potatoes	2.500	0.633	1.511	4.023
Fodder maize	0.930	0.231	0.600	1.472
Onions	2.015	0.413	1.445	3.128
Vegetables	0.818	0.156	0.530	1.115
Other	0.876	0.113	0.653	1.069
Expected yield indices (/100 in estimation for scaling purposes)				
Cereals	100.910	3.382	92.647	104.902
Grassland	103.237	4.099	94.691	109.078
Sugar beets	106.949	8.335	91.952	127.030
Potatoes	94.576	1.904	90.386	97.193
Fodder maize	106.612	3.987	100.480	115.588
Onions	92.550	3.282	85.323	101.882
Vegetables	108.451	7.744	83.548	218.187
Input price indices (normalized by the price of fertilizer)				
Pesticides	0.724	0.147	0.450	1.000
subsidies	0.571	0.495	0.000	1.000
Fixed cost indices (/100 in estimation for scaling purposes)				
Farm size	118.000	18.000	48.000	198.000
Coefficient of variation of the normalized expected output price indices ^{a)}				
Cereals	0.182	0.121	0.058	0.469
Grassland	0.124	0.074	0.044	0.309
Sugar beets	0.129	0.077	0.021	0.329
Potatoes	0.397	0.200	0.063	0.816
Fodder maize	0.116	0.060	0.037	0.200
Onions	0.542	0.155	0.242	0.840
Vegetables	0.121	0.067	0.030	0.340
Other	0.121	0.093	0.047	0.314

^{a)} For scaling purposes and clarity of estimation results, the ratio of coefficients of variation are divided by 10.

The large differences in output price volatility are reflected in the coefficients of variation of output prices (Table 2.3). Potatoes and onions experienced much larger price variations than other land uses.

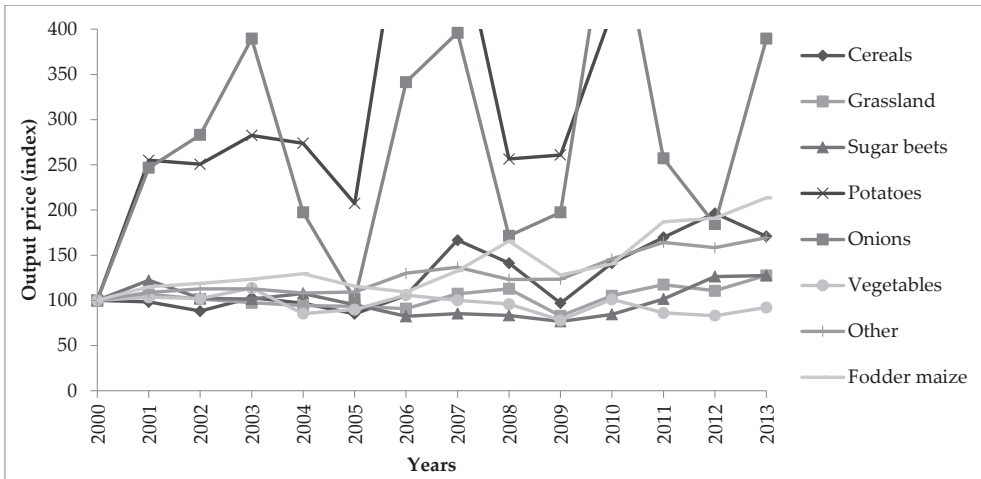


Figure 2.1: Changes in nominal output prices from 2000 to 2013. Values are normalized by setting the price in the base year (2000) to 100

2.4 Empirical Model

As indicated in equation 1 the allocation of land among different production activities for a utility-maximizing producer does not depend only upon output and input prices, and fixed input quantities, but also depends upon the variation in output prices in relation to farm technology and the producer's degree of risk-aversion. Given the land-use share equations for a utility-maximizing producer developed in the theoretical model we have specified the following reduced-form land-use share equations:

$$S_{hit}^* = \varphi_{hi} + \sum_{j=1}^J \beta_{ij} x_{jt} + \sum_{m=1}^M \rho_{im} q_{mt} + \sum_{k=1}^K \gamma_{hk} z_{kht} + \omega_i g_t + \sum_{r=1}^R \delta_{ir} v_{irt} + \lambda_i T_t + u_{it} \quad , h=1, \dots, H; i=1, \dots, I; t=1, \dots, T \quad (3)$$

Where S_{hit}^* represents the N_{hit} land-use shares of crop i in region h in year t ; φ_{hi} represents the region-specific intercept for region h and land use i ; β_{ij} represents the coefficients for normalized input and output prices j for crop i ; x_{jt} represents the normalized input and output prices j in year t ; ρ_{im} represents the coefficients of yields m for crop i ; q_{mt} represents the yields m in year t ; γ_{hk} represents the coefficients of fixed factors k for region h ; z_{kht} represents the fixed input factors k for region h in year t ; ω_i represents the coefficient for crop i for the presence of direct income payments, g_t represents the direct income payments dummy trend, δ_{ir} represents the coefficients for the ratios of the coefficients of variation of the expected prices r for crop i ; v_{irt} represents the ratios of the coefficients of variation of the expected alternative prices r with respect to expected prices i in year t ; λ_i represents the coefficient of crop i for the trends; T_t represents the time trend; and u_{it} represents the unobservable effects that affect land-use change for crop i in year t .

Equation 3 specifies the share of land use for each crop i in region h in year t . Because only relative prices matter, the model has been made homogeneous of degree zero by normalizing the standardized output prices and the standardized price of pesticides using the price of fertilizer. Each land use share equation only includes expected output price of its own land use and not expected output prices of alternative land uses in order to avoid multicollinearity. Due to data limitations, the fixed input quantities (z_{hkt}) are only represented by the average farm size per region per year and not allocated to individual land uses. A time trend has been included to account for crop-specific trends in land-use shares.

We assume the covariances of output prices to be zero. In reality, the covariances are not zero, but the large amount of covariance values caused multi-collinearity problems. For a producer,

the covariance of alternative products may be of importance in deciding upon land allocation. However, by estimating the effect of the ratios of the coefficients of variation all alternative land uses are taken into account.

We tested for censoring from below, meaning that there is a lower bound of zero for all land use shares. In case many land use shares actually take the value zero this could lead to inconsistent estimates of the parameters (Fezzi and Bateman, 2011). The results, provided in Table 2.2, show that censored observations are only present for vegetables, but not enough that inconsistent estimates of the parameters may be expected. This, together with the few non-zero observations for crop shares (see Table 2.2) means that we do not have to take sample selection problems into account. We therefore estimated the land-use share equations as a system using the seemingly unrelated regression (SUR) technique taking into account that the disturbances from different share equations are likely to be correlated because of common unobservable factors (Fiebig, 2001). This correlation could have several causes, such as weather, policy changes affecting the agricultural sector as whole, or economy-wide shocks. The yearly observations over the same study areas lead to a panel that required a fixed-effects transformation of the SUR regression. Because we deal with national values for both price and yield indices, a fixed effects transformation using deviations from the mean was not possible. We therefore chose a first-difference transformation on the model of the eight land-use shares:

$$\begin{aligned} (S_{hit}^* - S_{hit-1}^*) = & \sum_{j=1}^J \beta_{ij} (x_{ji} - x_{ji-1}) + \sum_{m=1}^M \rho_{im} (q_{mi} - q_{mi-1}) + \omega (g_i - g_{i-1}) \\ & + \sum_{k=1}^K \gamma_{hk} (z_{hkt} - z_{hkt-1}) + \sum_{r=1}^R \delta_{ir} (v_{irt} - v_{irt-1}) + \lambda_i + (u_{it} - u_{it-1}) \end{aligned} \quad h=1, \dots, H; i=1, \dots, I; t=1, \dots, T \quad (4)$$

Equation 4 implies that the intercept (φ_{hi}), which represents the region-specific effect, cancels out. The new intercept λ_i represents the coefficient of the crop-specific trend in equation 3. The transformed explanatory variables are composed of the first-differenced expected output prices (\hat{p}_{it}), first-differenced input prices (\mathbf{w}_i), first-differenced yields per hectare (q_{mi}), first-differenced average farm size (z_{hkt}), first-differenced dummy trend representing the presence

of direct income payments (g_t), and the first-differenced ratios of the coefficients of variation $(v_{irt} - v_{irt-1})^2$. Note that the dummy time trend for government subsidies transforms into a dummy representing the presence of direct payments. Tables 2.2 and 2.3 list the dependent and explanatory variables and their descriptive statistics.

Because all land-use shares together must sum to 0 in the first-differenced model, estimating all the land-use equations together results in a singular covariance matrix of error terms. While there are various ways to handle this singularity problem (Takada *et al.*, 1995), we decided to drop the residual equation 'other' from the system (Fezzi and Bateman, 2011). The residual equation can then be recalculated because, by definition, the land-use shares must sum to 1.

2.5 Results

We tested the contemporaneous correlation using the Breusch-Pagan test. The null hypothesis (i.e., no contemporaneous correlation) was rejected at the 1% level ($\chi^2(21) = 274.101$ and $P < 0.001$). This suggests that there is significant correlation because common elements exist in the seven equations that relate the equations through their residuals. The strongest correlations occurred between the residuals for wheat and meadows (33%) and potatoes and onions (22%). We tested for groupwise heteroskedasticity using the Lagrange Multiplier test. The null hypothesis (i.e., no groupwise heteroskedasticity) was rejected at the 1% level of significance for each of the seven equations. This means that the variances are constant over time within the equations, but differ between them. We tested for groupwise autocorrelation using the Durbin-Watson test. For all land uses the null hypothesis (i.e., no-autocorrelation) was rejected at the AR(1) level. This result means that there is either positive or negative

² Note that with first-differencing the panel is reduced by one year; i.e. observations start as of the second year of observations in the original panel. Moreover, first-differencing only occurs between time periods and not between regions or land uses.

autocorrelation and that the different error terms are correlated. Hence, statistical efficiency increases by estimating the seven equations as a system, and SUR is therefore the appropriate estimation method. Without SUR, the observed heteroskedasticity and autocorrelation would lead to biased and inconsistent estimates.

Table 2.4 summarizes the estimated regression coefficients for the seven land-use share equations. The table consists of two parts. The upper part of the table reports the regression coefficients of all variables except those relating to risk. The lower part of the table reports the regression coefficients for perceived risk due to price volatility. Moreover, the χ^2 value for all equations except for vegetables was significant at the 1% level. For vegetables, the χ^2 value was significant at the 5% level. This means that at least one of the regression coefficients in the model does not equal zero. Hence, we can be confident that the dependent variable is correlated with the individual variables. The coefficients of the land-use equations were generally small, indicating that land-use change is a slow process. We will discuss the estimation results for all variables except those relating to risk in the next section.

2.5.1 *Non-risk estimation results*

An increase in the expected output price of a particular land use is expected to lead to an increase in the share of that particular land use. Only grassland showed a negative and significant coefficient (Table 2.4), which supports this hypothesis. In the Netherlands, grassland is mainly associated with dairy farming. Dairy farming has been subject to quota restrictions for the whole observation period; making it more difficult to increase milk production following an increase in the output price of milk. Using the expected prices and land use shares of 2013 we calculated the elasticities with respect to output price of the land use shares. Table 2.5 shows the resulting percentage change in land shares, taking into account the effect of a 1% increase in a particular output price on its own and on alternative land use shares. All percentage changes in land share are inelastic with respect to its output price. This

is as expected; land use change is a slow process and is dependent on many other factors such as farm technology. Sugar beet and potatoes show the highest percentage change in land share (respectively 0.514 and 0.692 percent), grassland the lowest (-0.231 percent).

Yield per ha is assumed to have a positive effect on the land use share because yield increase makes producing the crop more profitable. For cereals and potatoes an increase in the expected yield leads to a significant increase in land-use share. For sugar beet, grassland and onions, an expected yield increase has a significant negative effect. Again, for both sugar beet and grassland, this may have to do with the quotas, restricting the ability to increase yields. For onions, this result might be counter-intuitive, but may be caused by the large fluctuations in yield for this crop.

When subsidies are completely decoupled from production, they should not alter the production plan (Hennessy, 1998). However, production decisions may be affected indirectly because of the so-called *wealth effect*, increasing a farmer's wealth and thereby reducing his level of risk aversion (Finger and Lehmann, 2012; Hennessy, 1998). Previous studies found that this may have some impact on crop allocation (Sckokai and Moro, 2009; Koundouri *et al.*, 2009). This would mean that due to the single farm payments (SFP), farmers are more willing to cultivate crops with a large price volatility. We find a positive and significant effect for cereals, sugar beet and grassland and a negative and significant effect for potatoes. Due to the decrease in the share of potatoes, a crop with large volatility, we do not find indication of a wealth effect. For grassland and sugar beet, the increase in share may have to do with the fact that the introduction of SFP was accompanied by a reduction in production restrictions. The trend for subsidies may therefore not only represent the introduction of SFP, but also the wider on-going liberalization of the CAP.

An increase in the price of pesticides is expected to lead to a decrease in the share of any land use that uses pesticides at a high intensity, but to an increase in the land-use share for a land use that uses pesticides at a low intensity. For grassland, the price of pesticides had a

significant negative coefficient (Table 2.4). In contrast, potatoes and onions have a significant positive coefficient for pesticides. If the price of pesticides increases, this means that it becomes more favourable to cultivate these crops. Because fertilizer and pesticide use are positively correlated in intensive agriculture, this reasoning is in line with that of Fezzi and Bateman (2011), who reported that the price effect of fertilizer depended on whether the crop was nutrient-intensive or not.

Since fixed inputs are not crop-specific we neither expect positive nor negative coefficients for average farm size. The coefficients representing average size showed little effect on the land-use shares (i.e., all values >-0.023 and <0.016 ; Table 2.4). For cereals, sugar beet, onions and vegetables small significant effects were found.

The constant represents the overall trend in the land-use shares of the different crops. There was a positive and significant trend for sugar beet, potatoes and fodder maize and a negative and significant effect for grassland (Table 2.4).

2.5.2 Risk estimation results

The lower part of Table 2.4 reports the ratios of the coefficients of variation of the prices of two land uses as a measure of perceived risk due to the expected price volatility of the two land uses. The advantage of using the ratios of coefficients of variation rather than variances and covariances results from the fact that it accounts for the risk-averse producer who compares the alternative crop with the current crop. In the lower half of Table 2.4, the values equal the coefficient of variation of the alternative crop (listed in the rows of the table) divided by the coefficient of variation of the current crop (listed in the columns of the table). We tested each of the land use share equations for model differences with and without the ratios of the coefficients of variation using the likelihood ratio test. For all land use shares, except for vegetables, the null hypothesis was rejected at the 1% level. For vegetables the null hypothesis

was rejected at the 5% level. Hence, test results showed that adding the ratios of the coefficients of variations to the model significantly improved the model fit. The results show many significant positive and negative coefficients, indicating that the ratios of the coefficients of variation successfully captured differences in the perceived risk. This is consistent with previous work by Sckokai and Moro (2006) that highlighted the impact of cross-crop effects on both the relative price and the variability of income.

Suppose we have the ratio of coefficients of variation (CV) of the output prices of two crops: $CV \text{ crop Y} / CV \text{ crop X}$. A positive sign implies that an increase in the ratio leads to an increase in the share of land allocated to crop X. So, for a risk-averse producer this means that when the price volatility of crop Y increases compared to that of crop X the land share of crop X increases. This may imply that crops X and Y are substitutes. With complements or risk-loving producers, an increase in the relative price volatility of crop Y leads to a reduction in the land share of crop X. So, in case of complements the coefficient has a negative sign. Hence, the likelihood for land use change depends on whether the crops are complements or substitutes and on the degree of risk aversion perceived by the producer.

For cereals (column 1 of Table 2.4), the ratio of the coefficients of variation with respect to sugar beet, fodder maize and vegetables showed a negative and significant coefficient. With respect to sugar beet, the negative sign implies that cereals and sugar beets are considered complements. This means that a smaller area of cereals would be grown if the price variation of beets increases compared to the price variation of cereals. This result is as expected because the most common crop rotation scheme in the Netherlands involves cereals, sugar beet and potatoes. The ratios of the coefficients of variation with respect to potatoes, grassland, onions and other show positive effects at the 1% significance level. This means these crops are substitutes for cereals. More relative price variation for these crops leads to an increase in the land share of cereals. For potatoes this result is unexpected. A possible reason may be that

especially seed potatoes are also grown outside the common crop rotation of cereals, sugar beets and potatoes.

For sugar beets (column 2 of Table 2.4), the ratios of the coefficients of variation with respect to cereals, potatoes and vegetables were significant and negative, indicating that these are complementary products because of crop rotation requirements. Grassland, fodder maize, onions and other had a significant and positive effect, indicating that they are substitute products.

For potatoes (column 3 of Table 2.4), sugar beets, fodder maize and vegetables were complements. Sugar beet is a complement because of crop rotation requirements, whereas onions were substitutes. Cereals does not show the expected negative sign, whereas fodder maize does not show the expected positive sign. A possible explanation may be that rotation schemes only allow limited cultivation of potatoes, which leads farmers to rent land from dairy producers to cultivate potatoes.

Grassland and fodder maize are production activities that are related to dairy production. For grassland (column 4 of Table 2.4), the ratios of the coefficients of variation for fodder maize had a large negative and significant effect. This is expected, because both are grown for dairy production and can therefore be seen as complements. Also, potatoes can be seen as a complement as discussed previously. The ratio of coefficients of variation of vegetables showed a positive and significant effect, meaning that they can be seen as substitutes. For the other crops, onions and cereals, the estimated coefficients were negative and significant.

For fodder maize (column 5 of Table 2.4) the estimated coefficients were low and often not significant. A possible explanation for this could be milk quotas, which have been enforced throughout Europe as part of the CAP and are still binding in the Netherlands. If producers produce at the quota level, a change in profit will not directly lead to a change in land use. Previous studies showed that quota hamper changes in land use (Huettel and Jongeneel, 2011; Piet *et al.*, 2012). Another explanation may be that land used for

dairy production is more difficult to change compared with land used for crop production. This is due to the relatively large amount of fixed capital required for dairy production and the fact that a large part of the soils in the Netherlands are not suitable for crop production. Significant coefficients are however observed for sugar beets and potatoes, acting as a substitute, and for onions, acting as a complement.

For onions (column 6 of Table 2.4), the volatility in prices is so high (figure 2.1) that we argue that the degree of risk the crop carries is more important than being part of a crop rotation system. Onions are the smallest land use; therefore producers may not be fully specialized in producing onions. This may lead producers to set aside some of their land for risk-loving behaviour. The ratios of the coefficients of variation of onions with sugar beets, potatoes, and vegetables had significant negative effects, indicating risk-loving behaviour.

For vegetables (column 7 of table 2.4), almost none of the ratios of the coefficients of variation were significant. This is consistent with our idea that vegetables do not function in a common rotation scheme with the other crops considered and that changes in vegetable production largely take place within its own category. Nonetheless, we found low, but significant and positive values for cereals, sugar beet and fodder maize.

Table 2.4: Estimation results (regression coefficients) using the system of land use^{a), b), c)}

	Cereals	Sugar Beet	Potatoes	Grassland	Fodder Maize	Onions	Vegetables
Output price	0.022 (0.012) *	0.039 (0.008) ***	0.025 (0.005) ***	-0.230 (0.056) ***	0.010 (0.005) *	0.001 (0.001) ns	0.002 (0.005) ns
Yield per ha	0.026 (0.013) **	-0.132 (0.021) ***	0.065 (0.031) **	-0.956 (0.181) ***	-0.085 (0.067) ns	-0.059 (0.011) ***	0.000 (0.000) ns
Subsidies	0.001 (0.002) ns	0.004 (0.001) ***	-0.014 (0.003) ***	0.015 (0.003) ***	-0.001 (0.002) ns	0.002 (0.001) ***	-0.000 (0.000) ns
	-0.003	-0.001	0.081	-0.144	-0.014	0.005	0.002

Pesticide price	(0.008) ns	(0.002) ns	(0.012) ***	(0.021) ***	(0.009) ns	(0.001) ***	(0.001) ns
Farm size	-0.023 (0.007) ***	-0.009 (0.002) ***	0.003 (0.003) ns	0.016 (0.014) ns	0.002 (0.005) ns	0.004 (0.002) **	0.003 (0.002) *
Constant	0.002 (0.002) ns	0.002 (0.001) ***	0.010 (0.002) ***	-0.027 (0.006) ***	0.002 (0.001) ***	-0.001 (0.001) ns	-0.000 (0.000) ns
Ratio of coefficients of variation (rows represent nominator, columns denominator)							
Cereals		-0.010 (0.003) ***	0.299 (0.053) ***	-0.047 (0.017) ***	0.018 (0.015) ns	0.019 (0.009) **	0.007 (0.003) ***
Sugar Beet	-0.309 (0.096) ***		-0.132 (0.023) ***	-0.019 (0.015) ns	0.059 (0.014) ***	-0.061 (0.016) ***	0.006 (0.003) *
Potatoes	0.034 (0.012) ***	-0.017 (0.003) ***		-0.034 (0.011) ***	0.023 (0.004) ***	-0.046 (0.009) ***	-0.002 (0.002) ns
Grassland	0.442 (0.130) ***	0.061 (0.008) ***	0.043 (0.031) ns		0.004 (0.006) ns	0.051 (0.037) ns	-0.018 (0.016) ns
Fodder Maize	-0.576 (0.166) ***	0.012 (0.004) ***	-0.465 (0.072) ***	-0.357 (0.025) ***		0.068 (0.016) ***	0.012 (0.005) **
Onions	0.056 (0.018) ***	0.008 (0.001) ***	0.112 (0.021) ***	-0.022 (0.004) ***	-0.017 (0.002) ***		-0.000 (0.001) ns
Vegetables	-0.088 (0.026) ***	-0.051 (0.006) ***	-0.399 (0.073) ***	0.135 (0.027) ***	-0.001 (0.007) ns	-0.131 (0.018) ***	
Other	0.097 (0.036) ***	0.076 (0.014) ***	0.510 (0.080) ***	-0.387 (0.062) ***	0.015 (0.016) ns	0.047 (0.021) **	0.010 (0.009) ns

^{a)} In the lower half of the table, the values equal the variance of the alternative crop (listed in the rows of the table) divided by the variance of the current crop (listed in the columns of the table).

^{b)} Standard error in parentheses.

^{c)} Where (*), (**), and (***) represent significance 10, 5 and 1% level respectively, and ns means not significant.

Table 2.5: Elasticities of land use with respect to price.

	elasticity
Cereal	0.174
Grassland	-0.231
Sugar beet	0.514
Potatoes	0.692
Fodder maize	0.079
Onions	0.119
Vegetables	0.357

2.6 Discussion and Conclusions

The European Union's CAP is shifting away from market and price support towards market liberalization and decoupled payments. The resulting increasingly volatile output prices and farm incomes pose challenges to agricultural producers that affect the competitive positions of various agricultural land uses. The objective of the present study was to assess the effect of volatile agricultural output prices on changes in agricultural land use since 2000 in the Netherlands.

Our analysis used data on 66 Dutch agricultural regions from 2000 through 2013 to analyse land-use decisions. We defined eight land use activities: production of cereals, grassland, sugar beets, potatoes, fodder maize, onions, vegetables, and other crops. For each land use, we established restricted profit functions that depended on expected output prices, variable input prices, the presence of direct payments, crop yields, the quantity of fixed inputs, and the ratios of coefficient of variation of expected output prices with those of alternative crops. Coefficients of variation were used in order to obtain a unitized measure of risk. Using ratios enabled us to distinguish between complements and substitutes in farmer's activities. Land-share equations were estimated using a multiple-equation panel-data model to determine the contribution of increased price volatility to land-use change.

Our estimation of the non-risk variables showed that for all land-use shares except for grassland, an increase in the expected output price of a particular land use led to an increase in the share of that particular land use. This is consistent with previous research, which showed significant positive effects of output price on land-use responses and suggests that price expectations are important in land-use decision-making (Sckokai and Moro, 2006; Fezzi and Bateman, 2011). Regression coefficients for expected yield showed negative results for land uses where the level is dependent on quota restrictions, namely sugar beet and grassland. For these two land uses, the introduction of single farm payments leads to an increase in their share of land. However, this result may be related to easing the production restrictions for these products that accompanied the introduction of the single farm payments. Therefore, the variable may be more likely to represent the on-going liberalization of the CAP. An increase in the price of pesticides showed variations in their effects, suggesting that an increase in the price of pesticides favours land uses that use these chemicals less intensively. The average farm size in a region had little to no effect on the land-use shares.

The ratios of the coefficients of variation of the prices of two alternative land uses can be used as a measure of expected relative price volatility. Two main conclusions can be drawn based on the present results. First, the results show many significant positive and negative coefficients, indicating that relative price variation matters and serves as a proxy for the degree of perceived risk. Risk-loving behaviour was observed for onions and potatoes. Producers only devoted a small proportion of their land to these activities. These results differ from those of Sckokai and Moro (2006), who confirmed their hypothesis of risk-averse behaviour for all types of farms. A possible explanation may be the unit of analysis; producers may be risk-averse overall, but may not show risk-averse behaviour for all activities.

Second, changes between land uses depend on whether production activities are complements or substitutes. For dairy farming, fodder maize and grassland appear to be complements. For arable farming, cereals, sugar beets, and potatoes appear to be

complements, whereas onions and grassland appears to be a substitute. This is consistent with Philippidis and Hubbard (2003) who find a change from oilseeds to cereals and a change from cattle to milk under the Agenda 2000 reform. Vegetables is not cultivated in rotation systems with other crops, which is reflected by the low response in relation to other land uses.

The complements within dairy farming and the complements and substitutes within arable farming may indicate competition within both categories of land use, and separation between them. A producer may view alternative production decisions only within the context of either arable farming or dairy farming depending on their current production activities. Switches between arable and dairy farming would involve higher transaction costs. This difference may also result from the perceived difficulty of converting grassland into other land uses due to soil conditions. Further research, splitting the land between arable and dairy sectors is necessary to test to what extent this hypothesis holds.

There are several caveats related to our approach. Data limitations did not allow us to disaggregate yields to the regional level. Because the regions had largely homogeneous soil types within a region but heterogeneous soil types between regions, disaggregating yields to the regional level could lead to more accurate estimates. Moreover, although we divided the Netherlands into regions based on homogeneity of soil type, we did not account for the effect of soil type on cultivation decisions. Since some soils may be unsuitable for some crops, a more precise version of our model would account for this. The increase in risk due to output price volatility may be partly offset by risk-reducing direct payments from the government (Ridier and Jacquet, 2002; Sckokai and Moro, 2006) and insurance measures such as forward contracts (Santos, 2002), which we did not account for in our analysis. By including a dummy trend for the introduction of single farm payments, we tried to account for changes in CAP policies. However, other policies, such as production restrictions (quotas) or environmental regulations, may lead to distortions in analysing the effects of risk.

Appendix Derivation from profit function to land use shares

Profit-maximizing producer

Assume a producer who takes the prices of inputs and outputs as exogenous. We define a profit function with multiple outputs (land uses or crops) that treats the total land area as a fixed allocable input:

$$\pi_{ht}(\mathbf{p}_t, \mathbf{w}_t, \mathbf{z}_{ht}, N_{ht}) \equiv \max_{n_{hit}} \sum_i \pi_{hit}(p_{it}, \mathbf{w}_t, \mathbf{z}_{ht}, n_{hit}), \quad h=1, \dots, H; i=1, \dots, I; t=1, \dots, T \quad (1)$$

Subject to:

$$\sum_i n_{hit} = N_{ht} \quad (2)$$

where $\pi_{ht}(\mathbf{p}_t, \mathbf{w}_t, \mathbf{z}_{ht}, N_{ht})$ represents the total profit for producer h in year t ; \mathbf{p}_t represents the vector of exogenous output prices in year t ; \mathbf{w}_t represents the vector of exogenous variable input prices in year t ; \mathbf{z}_{ht} represents the vector of quantities of fixed inputs for producer h in year t ; N_{ht} represents the total number of hectares to be allocated to different land uses by producer h in year t ; $\pi_{hit}(p_{it}, \mathbf{w}_t, \mathbf{z}_{ht}, n_{hit})$ represents the profit for a producer of land use i in year t ; p_{it} represents the output price of land use i in year t ; n_{hit} represents the number of hectares for producer h allocated to land use i in year t .

Exogenous output prices (p_{it}) differ among land uses and years, whereas exogenous input prices (\mathbf{w}_t) are the same for all land uses. The use of variable inputs differs among land uses. However, although the amount of fixed inputs differs among producers and years we make the restrictive assumption that land use depends on the total amount of fixed inputs on a farm. So, fixed inputs are not allocated to individual land uses. In this chapter, we will assume that there is no variation in soil type within regions. However, there is variation between regions as regions are divided on the basis of soil type. The total land area available to all producers is $N_t = \sum_h \sum_i n_{hit}$, which equals the total amount of agricultural land available in a specific year.

Assuming that output in terms of quantity of a crop (land use) is the product of a fixed exogenous yield per hectare (q_{hit}) and the number of hectares, equation 1 can be written as:

$$\pi_{ht}(\mathbf{p}_t, \mathbf{w}_t, \mathbf{q}_{ht}, \mathbf{z}_{ht}, N_{ht}) \equiv \max_{n_{hit}} \sum_i \{p_{it} \cdot q_{hit} \cdot n_{hit} - C(\mathbf{w}_t, n_{hit}, q_{hit}, \mathbf{z}_{ht})\} \quad (3)$$

$$\sum_i n_{hit} = N_{ht} \quad (4)$$

Where \mathbf{q}_{ht} is the vector of different crop yields for producer h in year t .

Because producers do not know the price for a given product at the time they make their production decisions, we must deal with *expected* output prices instead of *observed* output prices. Input prices are typically known at the time of purchase, and therefore producers do not let their land-use decisions be determined by their expectations on the variability of input prices (Chavas and Holt, 1990). Thus, equation 3 can be rewritten as:

$$E\pi_{ht}(\hat{\mathbf{p}}_t, \mathbf{w}_t, \mathbf{q}_{ht}, \mathbf{z}_{ht}, N_{ht}) \equiv \max_{n_{hit}} \sum_i \{\hat{p}_{it} \cdot q_{hit} \cdot n_{hit} - C(\mathbf{w}_t, n_{hit}, q_{hit}, \mathbf{z}_{ht})\} \quad (5)$$

where $E\pi_{ht}(\hat{\mathbf{p}}_t, \mathbf{w}_t, \mathbf{q}_{ht}, \mathbf{z}_{ht}, N_{ht})$ represents the expected profit for producer h in year t , and $\hat{\mathbf{p}}_t$ represents the vector for the expected output prices.

Utility-maximizing producers

Expected utility is determined by the expected profit defined in equation 5, the variance of profit, and the coefficients of absolute risk aversion per crop. The utility function (U_{ht}) can be denoted by the following equation (see e.g. Coyle, 1992):

$$U_{ht}(\hat{\mathbf{p}}_t, \mathbf{w}_t, \mathbf{q}_{ht}, \mathbf{z}_{ht}, N_{ht}, V\pi_{ht}) = E\pi_{ht}(\hat{\mathbf{p}}_t, \mathbf{w}_t, \mathbf{q}_{ht}, \mathbf{z}_{ht}, N_{ht}) - 0.5\alpha_h V\pi_{ht} \quad (6)$$

Where $U_{ht}(\hat{\mathbf{p}}_t, \mathbf{w}_t, \mathbf{q}_{ht}, \mathbf{z}_{ht}, N_{ht}, V\pi_{ht})$ represents the indirect utility for producer h in year t ; $V\pi_{ht}$ represents the vector of variance of profit for producer h and year t ; and α_h represents a vector of coefficients of absolute risk aversion for the different outputs for producer h .

Following the method of Coyle (1992), we assume that the variance of profit is given by:

$$\mathbf{V}\pi_{ht} = \mathbf{n}_{ht} \cdot \mathbf{V}\mathbf{p} \cdot \mathbf{n}_{ht}^T \quad (7)$$

where $\mathbf{V}\mathbf{p}$ represents the symmetric, positive, definite covariance matrix of output prices. \mathbf{n}_{ht} represents the vector of the number of hectares allocated to the different land uses for producer h in year t , \mathbf{n}_{ht}^T represents the transpose of \mathbf{n}_{ht} .

If we substitute the expected value of the profits (Eq. 5) and the expected variance of the profits (Eq. 7) into the expected utility function (Eq. 6), we obtain the following indirect utility function:

$$U_{ht}(\hat{\mathbf{p}}_t, \mathbf{w}_t, \mathbf{q}_{ht}, \mathbf{z}_{ht}, \mathbf{V}\mathbf{p}, N_{ht}) = \max_{\mathbf{n}_{ht}} U_{ht}(\hat{\mathbf{p}}_t \cdot \mathbf{q}_{ht} \cdot \mathbf{n}_{ht} - C(\mathbf{w}_t, \mathbf{q}_{ht}, \mathbf{n}_{ht}, \mathbf{z}_{ht}) - 0.5\alpha_{ht} \mathbf{n}_{ht}^T \cdot \mathbf{V}\mathbf{p} \cdot \mathbf{n}_{ht}) \quad , n_{ht} \in \mathbb{T} \quad (8)$$

The indirect utility function represents the relationship between the maximum attainable utility ($\max U$) and the exogenous variables $\hat{\mathbf{p}}_t$, \mathbf{w}_t , \mathbf{q}_{ht} , \mathbf{z}_{ht} , $\mathbf{V}\mathbf{p}$, and N_{ht} (Oude Lansink, 1999). This utility function has the following properties: increasing in expected output prices and yields, decreasing in variable input prices, decreasing in the variance of output prices, linear homogenous and convex in output prices, input prices and the variance of output prices (Coyle, 1990).

The variable of absolute risk aversion α_{ht} is measured per producer and per crop. For any value of $\alpha_{ht} > 0$, the producer is risk-averse (Chavas and Pope, 1982). In the case of a risk-neutral producer ($\alpha_{ht}=0$), the term that captures the risky environment, which equals the risk coefficient multiplied by the variance of profit ($0.5\alpha_{ht}\sigma_\pi^2$) disappears from the equation.

The Lagrangian for the indirect utility function (Eq. 8), denoted L_{ht}^U , equals:

$$L_{ht}^U = \left(\hat{\mathbf{p}}_t \cdot \mathbf{q}_{ht} \cdot \mathbf{n}_{ht} - C(\mathbf{w}_t, \mathbf{q}_{ht}, \mathbf{n}_{ht}, \mathbf{z}_{ht}) - 0.5\alpha_{ht} \mathbf{n}_{ht}^T \cdot \mathbf{V}\mathbf{p} \cdot \mathbf{n}_{ht} + \lambda_{ht} (N_{ht} - \mathbf{n}_{ht}) \right) \quad (9)$$

where λ_{ht} represents the shadow price of the land constraint. The necessary first-order conditions for an interior solution are:

$$\frac{\partial L_{ht}^U}{\partial \mathbf{n}_{ht}} = \hat{\mathbf{p}}_t \cdot \mathbf{q}_{ht} - C'(\mathbf{w}_t, \mathbf{q}_{ht}, \mathbf{n}_{ht}, \mathbf{z}_{ht}) = \boldsymbol{\alpha}_h \cdot \mathbf{Vp} \cdot \mathbf{n}_{ht} - \lambda_{ht} \quad (10)$$

$$N_{ht} - \mathbf{n}_{ht} = 0 \quad (11)$$

Equation 10 allocates the available land among land uses based on the marginal utility from each land use. The input constraint in Eq. 11 is binding if we require an interior solution. Solving equations 10 and 11 gives the optimal allocation of land use i for producer h in year t ³:

$$\mathbf{n}_{ht}^U = (\hat{\mathbf{p}}_t, \mathbf{w}_t, \mathbf{q}_{ht}, \mathbf{z}_{ht}, \mathbf{Vp}, N_{ht}) \quad (12)$$

Land-use Share Equations

Now, let us assume that the optimal allocation of land (\mathbf{n}_{ht}^U) is homogeneous of degree 1 in N_{ht} ⁴. For the utility-maximizing producer, we then get:

$$\mathbf{n}_{ht}^U(\hat{\mathbf{p}}_t, \mathbf{w}_t, \mathbf{q}_{ht}, \mathbf{z}_{ht}, \mathbf{Vp}, N_{ht}) = \mathbf{n}_{ht}^U(\hat{\mathbf{p}}_t, \mathbf{w}_t, \mathbf{q}_{ht}, \mathbf{z}_{ht}, \mathbf{Vp}, 1) N_{ht} \quad (13)$$

This means that if the total amount of land decreases with the factor b , the amount of land allocated to land use i also decreases with the factor b . Equation 13 can be rewritten towards a land-use share function (see equation 1 in the main text).

³ Note that upon solving equation 12 the variable of absolute risk aversion α_{hi} drops from the equation.

⁴ Homogeneity of degree 1 in land is a necessary assumption to specify the model in land use shares because this implies that any added land will be split up exactly among crops.

CHAPTER 3. THE DYNAMICS OF DAIRY LAND USE CHANGE WITH RESPECT TO THE MILK QUOTA REGIME¹

Abstract

This chapter analyses the sequence of changes in land used for milk production on dairy farms before, during, and towards the abolition of milk quotas. Using a unique dataset comprising farm level data of the Netherlands between 1971 and 2011 we estimate two duration models, analysing the time period between increases and decreases in dairy land use. The impact of milk quota, socio-economic, farm income and economic-political variables on the likelihood of a farm changing its land use are assessed. Results show that changes are highly farm specific, but that quota abolition will lead to a more dynamic dairy sector.

¹ Paper by Esther Boere, Jack Peerlings, Stijn Reinhard and Wim Heijman, *European Journal of Agricultural Economics*. Doi: 10.1093/erae/jbv002

3.1 Introduction

Milk quota abolition, taking place in 2015 as part of the Common Agricultural Policy (CAP) reform, is expected to change the dynamics of (dairy) land use. Before milk quota implementation, European Union (EU) dairy policy consisted of price and income support provided through import levies, export subsidies, intervention buying and subsidies on domestic demand (e.g. school milk). Partly due to this price and income support overproduction in milk occurred, which led to the introduction of milk quotas in 1984. The total quota amount in the EU was secured at the 1981 level (+1%), while the distribution was country-specific. In the Netherlands, milk quotas were tied to land, potentially hampering quota trade and farmer's ability to change milk production. However, this rule was bypassed by transferring quota rights via the temporary lease of land, implying that land with quotas was leased for a very short period while immediately after this land was returned to the owner (Boots *et al.*, 1997). Leasing quota without land was officially introduced in 1990 and permanently transferring quota without land in 2006 (Productschap Zuivel, 2007). However, because quota trade was already well established both policy changes were basically formalities. During the 2003 Fischler reform it was decided that milk quotas were to be increased as of 2006-2007 in three yearly steps of 1.5% in total. An extra quota increase of 2% was introduced in the Health Check of 2008. Between 2009 and 2014, quotas have been subjected to a 1% yearly increase. Complete abolition in 2015 was affirmed by the EU's agreement of December 2013 (European Commission, 2013).

During the quota regime, milk quota can be seen as a farmer's most scarce production factor; in order to increase production, a farmer has to buy quota rights. Besides milk quotas, land is generally seen as the most scarce production factor in dairy farming in the Netherlands. Land strongly influences the level of milk production because it is needed for roughage production and grazing. Moreover, dairy farming is bound to environmental regulations limiting the manure application per hectare of land (RVO, 2014). In the Netherlands, manure policy

started in the early 1980s and follows nowadays the EU's Nitrates Directive, enforced in 1991. (European Commission, 1991; 2014b). In the absence of quota, land could therefore be seen as the most scarce production factor, making changes in land use relevant for both farms and policy makers. The presence and abolition of milk quotas is therefore expected to have an effect on the pace of changes, both positive and negative, of land use that takes place at a dairy farm.

The impact of milk quotas on the farm level is complex (Huettel and Jongeneel, 2011), but milk quotas are likely to hamper changes on dairy farms (Piet *et al.*, 2012). Existing research on the influence of milk quotas includes the impact on changes in farm size (Breustedt and Glauben, 2007; Huettel and Jongeneel, 2011; Zimmermann and Heckelei, 2012), production (Ooms and Peerlings, 2005; Breustedt and Glauben, 2007; Huettel and Jongeneel, 2011), farm characteristics (Gale, 2003; Ooms and Peerlings, 2005; Huettel and Jongeneel, 2011), market conditions, land mobility (Harrington and Reinsel, 1995) or a combination of them (Zimmermann and Heckelei, 2012). However, all these studies focus on the impact of milk quotas, but not on the time at which they occur.

The abolition of the milk quota system will make changes in dairy land use more relevant for expansions or reductions in milk production. In the context of policy changes that induce transitions it is therefore important to take both time and the length of time periods between changes in dairy land into account. The purpose of this chapter is to analyse the time period between two changes in land used for milk production on dairy farms and the direction of change, either positive or negative, before, during and towards the abolition of milk quota. This is relevant in order to assess the farm-specific impacts of milk quota abolition on the dynamics of land use change. We hypothesize that quota abolition will lead to more dynamics in the dairy sector, implying shorter time periods between land use changes, both positive and negative.

We define change in dairy land use as an increase or decrease of at least 10% in land used for milk production on a dairy farm. This may be achieved by buying or selling land, or by changing the use of land already present at the farm. Hence, this study focuses on analysing the dynamics of changes in land used for milk production and does not analyse the magnitude of land use changes. The 10% limit restricts changes to more substantial ones excluding small adjustments due to, for example, crop rotation. We define change relative to the size of the farm because we assume larger farms find it easier to change the use of a fixed amount of land than smaller farms.

We analyse the impact of determinants of land use changes on dairy farms using a duration model. The use of duration models within agricultural economics is relatively rare. Examples include Towe *et al.* (2008) who analyse whether the option to preserve farmland delays development decisions; Goncharova *et al.* (2008) who analyse the duration between investment spells in Dutch greenhouse farms; Burton *et al.* (2003), Kallas *et al.* (2010) and Läßle (2010), all analysing duration models in the light of organic farming adoption; Hynes and Garvey (2009) and Wynn *et al.* (2001) modelling the duration of farmer's entry into agri-environmental schemes and Väre (2006) who analyses the spousal effect on the timing of farmer's retirement. However, none of these allow for events to occur multiple times (e.g. different occasions of growth), and with different outcomes (e.g. both growth and decline). A notable exception is Francksen *et al.* (2012) who analyse the time towards expansion of milk quotas, allowing for different growth rates. However, they do not allow for negative growth and are not able to analyse the period prior to the abolition of milk quota. We take a different approach compared to the aforementioned studies by applying duration analysis to the pace of on-farm land use changes.

We further contribute to the existing literature by using a unique dataset comprising farm structure survey data of the Netherlands covering the period between 1971 and 2011. This allows us to analyse dairy farming before, during and towards the abolition of the milk quota

regime. We analyse the sequence of increases and decreases in land used for milk production with and without the milk quota regime which has to our knowledge not been done before. In the next section, we establish a theoretical model of land use change with the aim to show why a farmer is not continuously adjusting his land used for dairy farming. Section 3.3 describes the data and explains how our sample is split into increases and decreases in dairy land use. Section 3.4 presents the empirical model and estimation method for the duration model. Results are presented in section 3.5. Our conclusions and a general discussion follow in section 3.6.

3.2 Theoretical model

Farmers base their decision to change the amount of land used for dairy farming on their relative profitability compared to alternative land uses as represented by the shadow prices of land and based on the adaptation costs related to changing land use. To explain why farmers are not continuously adjusting their land used for milk production we present a simple static model applied to two production activities; milk and other production. Formulating a full dynamic model, for example using value functions such as in Goncharova *et al.* (2008), goes beyond the scope of this chapter for two reasons. Firstly, our model does not entail a single optimal strategy; a farmer might either increase or decrease its land used for dairy production which may change his revenues obtained from both dairy farming and other activities. Secondly, our model does not work towards one optimal point in time under the assumption that the farmer has complete foresight (see e.g. Bellman, 1957). Rather, we assume that the farmer is continuously faced with changes in the factors determining his land use. As a result, he re-evaluates his land used for dairy farming on a yearly basis.

Suppose we have a farmer who can choose to allocate his land between milk production and other production, depending on factors that determine profit of milk or other production and

adaptation costs. When these factors change the farmer may decide to change his land use.

Profit in both cases is given by:

$$V_n(L_n^i, L_n^e, q_n) = \max_{L_n^i, L_n^e} \left\{ \pi_n(L_n^i, L_n^e, q_n) - C(\Delta L^i, \Delta L^e, q_n) \right\} \quad (1a)$$

$$V_o(L_o^i, L_o^e, q_n) = \pi_o(L_o^i, L_o^e, q_n) \quad (1b)$$

where $V_n(\cdot)$ represents net profit with new land use; π_n is the return from land with new land use; L_n^i and L_n^e are land used for respectively dairy farming and other production after the change in land use; C are the adaptation cost; ΔL^i represents the change in land used for dairy farming; ΔL^e represents the change in land used for other production; $V_o(\cdot)$ represents net profit with old land use; π_o is the return from land in case of old land use. L_o^i and L_o^e are land used for respectively dairy farming and other production in the case of old land use; q_n is a vector with new (expected) values of variables affecting return to land and adaptation costs.

Depending on whether $V_n(\cdot)$ or $V_o(\cdot)$ is larger the farmer decides whether or not to change land use:

$$R = \begin{cases} 1 & \text{if } V_n > V_o \quad (\text{land use change}) \\ 0 & \text{if } V_n \leq V_o \quad (\text{no land use change}) \end{cases} \quad (2)$$

where R is the farmer's decision whether to change land use.

Taking the first order derivatives of $V_n(\cdot)$ and $V_o(\cdot)$ with respect to the amount of land used for dairy production gives the shadow prices of land used for dairy production with and without land use change. If we compare both shadow prices and using (2) it is clear that:

$$p_n(L_n^i, L_n^e, q_n) - C'(\Delta L^i, \Delta L^e, q_n) \leq p_o(L_o^i, L_o^e, q_n) \leq p_n(L_n^i, L_n^e, q_n) \quad , \quad (3)$$

where $p_n(L_n^i, L_n^e, q_n)$ is the shadow price of land with the new land use, $C'(\Delta L^i, \Delta L^e, q_n)$ are the marginal adaptation cost, and $p_o(L_o^i, L_o^e, q_n)$ is the shadow price of land for milk production with the old land use. This implies that the shadow price of land can vary within a certain range before an actual land use change takes place. The size of the range is equal to the

adaptation costs; only a change in shadow prices large enough to cover adaptation costs will lead to land use change. Notice that land use change can be a reallocation of land on the farm but may also involve buying (leasing) or selling (renting out) land. For example, in case of buying land $p_n(L_n^i, L_n^e, q_n)$ would be the buying price.

A well-known class of models analysing decision making of farms that are faced with changes in the factors determining land use are household production models. Household production models include a production unit that maximizes profit and a household unit that maximizes utility. In these models the household supplies factor inputs to the production unit and receives income in return. Recent applications of these models include Glauben *et al.* (2012) using a production model in a non-separable household decision framework, Carter and Yao (2002) in a land allocation setting and Glauben *et al.* (2009) using a dynamic model for farm succession. Such farm household models take the shadow price of land to depend on output prices, variable inputs prices, and the amount of land, labour and capital. Moreover, via the household that maximizes utility and via the adaptation costs, household characteristics play a role. Not only variables endogenous to the household, but also exogenous variables are of influence. These include the economic-political environment including changes in policy and market conditions.

The farmer's decision whether or not to change his amount of land use thus depends on policy-variables K , farm-specific characteristics Z_h , farm-income variables Q_h and economic-political variables M , where the index h refers to farm household. Together these variables constitute q_n . Each year, this yields the farmer the binary choice explained in equation (2), depending on q_n . In case $R=0$ (eq 2), the period towards land use change is enlarged by one year before the farmer re-evaluates his land allocation decision.

3.3 Data and descriptive statistics

The data was obtained from the Farm Structure Survey, covering all farms in the Netherlands with at least ten dairy cows between 1971 and 2011 (Statistics Netherlands, 2013). In this section we explain how this sample is composed and describe the factors that determine profit of milk production and adaptation costs, as introduced in the theoretical model.

3.3.1 Study sample

The complete database contains about 2 million observations from around 140,000 farms with at least 10 cows. The definition of a farm with milk production as a farm that owns at least 10 cows is chosen because this excludes farms for which dairy farming is not an economic activity. It does include mixed farms that may expand and specialize in dairy farming during the sample period. The data set includes both farms that enter after 1971 and farms that exit before 2011. We therefore deal with an unbalanced panel. There is a large amount of right truncation; 67% of all farms are first observed in 1971, while only 6.2% of all farms are observed during the entire sample period. This implies a large exit of farms during the sample period, which might either be due to farms specializing in other activities besides dairy farming (farms who went from 10 cows or more to anything below 10 cows), or to farms who stop farming altogether. Succession by a family member is treated as farm continuation.

In this chapter we limit our scope to those farms that increase or decrease their land used for milk production. We therefore split our sample into positive and negative land use changes. The event of land use change is defined as the time at which a farm changes its land used for milk production with at least 10%. This may be a change in the use of land already existing on the farm as well as a change in the use of land through the purchase or sale of additional land. Land used for milk production is composed of grassland and fodder land, mainly composed of fodder maize in the Netherlands. Grassland and fodder land is not only used by

dairy cows, but also by other livestock such as beef cattle, sheep, goats and equidae. We correct for these using the livestock unit classification (LSU), which is based on livestock feed requirements expressed per hectare of land compared with feed requirements of a dairy cow (Eurostat, 2013). Hence, the amount of land used for milk production is measured as the share of dairy herd in the total number of LSU multiplied by the total amount of grassland and fodder land on farm.

For every farm, the years between two changes of at least 10% in land used for milk production are measured. For the first observation of land use change the time period is not observed because we do not know when the previous change took place. In order to overcome this partial censoring to the left, the first period of change in the analysis is measured at the second year for which land use change is observed. In order to ensure a continuous dataset we analyse the time period from a change in land use to either an increase or a decrease in dairy land. It therefore does not matter whether the first observation is an increase or a decrease in dairy land. Hence, our subsample includes only farms with at least two years in which a change of at least 10 per cent in dairy land is observed. With every subsequent year in the sample it is possible for the time period to increase by one year. This causes the data to be truncated to the left, the upper two lines in figure 3.1 that display the time period towards an increase and decrease in land show that this is indeed the case. The subsample of increases in land use consists of 225,342 observations, the subsample of decreases in land use consists of 150,585 observations. In total, 68,412 farms observe at least one increase or decrease (or both) in land used for dairy farming.

The bottom two lines in figure 3.1 display the share of increases and decreases; the number of farms facing a change of at least 10% in dairy land divided by the total number of farms per year. Land use increases and decreases largely develop parallel to each other. This is obvious because land is a scarce production factor and for farms to increase others must decrease. However, we do not take the magnitude of changes into account. With respect to the time

period towards increases in land use, an increase in time period until 1985 (just after the quota introduction) is observed, followed by a drop until the early 1990s. After that, fluctuations between 3 and 3.5 years take place. For the time period towards decreases in land use, the same increase is observed until 1985, after which the time period stabilizes until 1993, then drops and stabilizes around 3 years. In the years after the quota introduction, average land use changes have taken slightly longer. This might be explained by the necessary reduction in milk production, reducing the need to increase dairy land use, or by the adaptation period for transferring quota without land. With respect to the share of increases and decreases in dairy land use, the course is opposite in the period just after the introduction of the milk quota regime. Here, the share of decreases is increasing and the share of increases is slightly decreasing. Overall, the share of farms experiencing changes in land use is declining over the past decennium. This may have to do with the trend towards fewer but larger farms, requiring more hectares of land for a change of at least 10%.

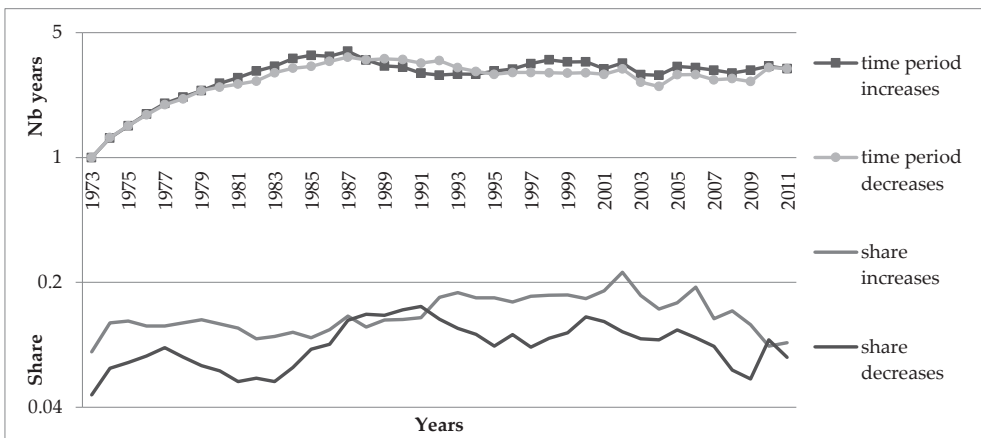


Figure 3.1: Share of farms facing an increase or decrease of at least 10% in land use in total number of farms and the yearly average length of the time period before the change takes place (logarithmic scale).

3.3.2 Explanatory variables

The dependent variable in our model is the time period between two changes of at least 10% in land use. The time period is measured as the number of years between a change, either a decrease or an increase, in dairy land use.

The variables explaining the time period between two land use changes and adaptation costs are divided into quota variables (K), socio-economic variables (Z_h), variables related to the income of the farm (Q_h) and economic-political variables (M) (see section 3.2). The quota variables are a dummy representing whether there is a quota regime, a trend starting in 2003 when quota abolition was decided and a dummy variable for the years 1984-1986 explaining the adjustment to the quota regime.

Socio-economic characteristics of the farm are grouped to characteristics with respect to the farm operator and a variable regarding the continuation of the farm. In analysis on farm structural changes, commonly used characteristics with respect to the farm operator are age and age squared (Weiss, 1999; Goetz and Debertin, 2001; Glauben *et al.*, 2006; Breustedt and Glauben, 2007), part-time or full-time operation of the farm (Weiss, 1999; Glauben *et al.*, 2006; Breustedt and Glauben, 2007), whether the farm operator followed an agricultural education and the level of education, gender and marital status (Weiss, 1999). In this chapter we use age and age squared, whether the farm operator works full-time or part-time on the farm, whether the farm operator followed an agricultural education and his level of education, described by a dummy variable indicating whether he completed at least post-secondary occupational education. We included both age and age squared because previous studies observed life cycle patterns of farms (Weiss, 1999; Gale, 2003).

Variables related to the continuity of the farm are usually grouped to ownership of the land (Goetz and Debertin, 2001; Glauben *et al.*, 2006; Breustedt and Glauben, 2007; Francksen *et al.*, 2012), the number of family members (Weiss, 1999; Breustedt and Glauben, 2007) and whether there is a successor. We used the presence of a successor as a characteristic measuring

continuation of the farm. Furthermore, we included an interaction term between the variables age and successor because we assume that having a successor becomes increasingly important with age. For variables related to the farmer's education and successor we did not have information on all years of the observation period. For these variables, we filled in the missing years where the farm operator did not change. However, some missing values remained, for which the observations are dropped during estimation.

Commonly used variables related to the income of the farm are output price (Rahelizatovo and Gillespie, 1999; Foltz, 2004; Breustedt and Glauben, 2007), government payments (Goetz and Derbetin, 2001; Breustedt and Glauben, 2007), input price (Rahelizatovo and Gillespie, 1999), capital (Rahelizatovo and Gillespie, 1999; Goetz and Debertin, 2001; Foltz, 2004; Breustedt and Glauben, 2007) and production per cow (Rahelizatovo and Gillespie, 1999; Foltz, 2004). Data limitations restricted us to use the change in total labour (hired and household labour), the total ha available on farm, the share of fodder land on farm, the number of cows on farm, the change in average milk production per cow and the change in yearly milk price as variables explaining income generated on farm. Including the change in the number of cows on farm may potentially lead to endogenous results. A change in dairy herd demands a corresponding change in land for dairy production. Conversely, as land use change takes place, this may have an effect on the change in the number of cows. Hence, the duration may help predict the change in the number of cows. We therefore used the amount of cows right after the last land use as a proxy for the change in cows.

Economic-political variables usually include population density, population growth and the unemployment rate (Goetz and Derbetin, 2001; Breustedt and Glauben, 2007). These variables do not seem to be relevant for individual Dutch dairy farmers. We restricted us to the yearly interest rate as a measure for investment costs. However, not considering the economic-political environment may lead to an overestimation of the milk quota effects. Following Burton *et al.* (2003) we therefore included a split time-trend with one variable running from

1971 to 1983, with the initial value -11, increasing by one and taking the value zero from 1984 on; and the other variable running from 1984 to 2011, taking the value zero for all years prior to 1984. Herewith, we aim to capture systematic changes in dairy land use change. A description of all variables used in the analysis can be found in Table 3.1.

The socio-economic characteristics of the farm and quota variables are estimated one year lagged, whereas changes in production variables (except for the number of cows) and the direction of land use change occur at the year of change. All changes are calculated with respect to the previous year instead of the previous change in land use to overcome endogeneity problems.

Table 3.2 shows the descriptive statistics for the explanatory variables for the subsample of farms without a change, and for growing and shrinking farms before and after the quota introduction. Except for the change in total labour, descriptive statistics between increases and decreases in land use do not differ much. Compared to the period before quota introduction, farm operators are older, more agriculturally educated and use more production factors in the period after quota introduction. Correlations between the dependent and independent variables showed that there are no correlations high enough to suggest multicollinearity can be expected.

Table 3.1: Description of variables

Variable	Explanation
<i>Quota variables (K_{it})</i>	
Quota	Dummy (1 between 1984-2011, 0 between 1971-1983)
Adjustment	Dummy variable for the years 1984-1986 explaining the adjustment to the quota regime
Transition	Time trend as of 2003, when the EU started to yearly increase milk quota
<i>Socio-economic characteristics (Z_{it})</i>	
Age	Age of the farm operator
Age squared	Age squared of the farm operator
Fulltime operator	Dummy whether the farm operator works full-time
Agricultural education	Dummy whether the farm operator followed an agricultural education
Occupational education	Dummy whether the farm operator completed at least post-secondary occupational education
<i>Continuity of the farm</i>	
Successor	Binary variable that takes the value 1 if the farm operator is over 50 years old and has a successor.
Age x successor	Interaction term between variables age and successor
<i>Farm income variables (Q_{it})</i>	
Share fodder land	Share of grassland and fodder land in total agricultural land
Production growth	Change in national average milk production w.r.t. the previous year in 100 kg per cow
Change in labour	Change in total labour (household + hired) w.r.t. the previous year in Full Time Equivalent (FTE)
Total ha land	Total land on farm in ha
Herd at previous change	Change in the number of cows w.r.t. the previous change
Change milk price	Change in milk price in €/kg w.r.t. the previous year
<i>Economic-political variables (M_{it})</i>	
Interest	yearly national average interest rate
Trend before quota	split time trend from 1971 to 1983, starting with -11, taking value 0 after 1983
Trend during quota	split time trend from 1984 to 2011, taking value 0 prior to 1984
<i>Dependent variable (Y_{it})</i>	
Time period	Time period equation: Years between a decrease or increase of at least 10% in land used for milk production

Table 3.2: Descriptive statistics of explanatory variables separated by increases and decreases in land use

Variable	no change		before quota				after quota			
	(n=1,620,028)		increases (n=77,063)		decreases (n=45,660)		increases (n=148,279)		decreases (n=104,925)	
	mean	std	mean	std	mean	std	mean	std	mean	std
<i>Quota variables (K_{ht})</i>										
Quota	0.49	0.50	0.00	0.00	0.00	0.00	0.96	0.20	0.96	0.19
Adjustment	0.09	0.29	0.00	0.00	0.00	0.00	0.12	0.33	0.12	0.33
Transition	0.51	1.72	0.00	0.00	0.00	0.00	0.70	1.76	0.64	1.75
<i>Socio-economic characteristics (Z_{ht})</i>										
Age	50.70	11.61	47.71	11.19	49.81	11.34	50.77	11.24	51.92	11.34
Age squared	3271	7194	2401	1105	2609	1144	2704	1164	2824	1182
Fulltime operator	0.93	0.26	0.97	0.16	0.97	0.18	0.97	0.18	0.96	0.19
Agricultural education	0.61	0.49	0.64	0.48	0.59	0.49	0.78	0.41	0.75	0.43
Occupational education	0.24	0.42	0.19	0.39	0.17	0.37	0.40	0.49	0.35	0.48
<i>Continuity of the farm</i>										
Successor	0.94	0.24	1.00	0.04	0.99	0.07	0.94	0.24	0.92	0.26
Age x Successor	46.94	16.21	47.53	11.34	49.34	11.87	47.14	16.22	47.34	17.45
<i>Farm income variables (Q_{ht})</i>										
Share fodder land	0.94	0.16	0.87	0.20	0.88	0.21	0.94	0.15	0.94	0.14
Production growth	0.81	1.04	0.63	0.65	0.67	0.66	1.06	1.30	1.06	1.28
Change in labour	-0.01	0.71	0.02	0.59	-0.03	0.61	0.01	0.78	-0.02	0.81
Total ha land	21.51	17.65	19.73	11.81	19.84	12.93	30.85	20.64	30.57	22.08
Herd at previous change			28.30	19.07	26.06	18.62	52.30	31.85	47.24	31.59
Change milk price	0.78	1.99	1.31	0.73	1.33	0.74	0.02	2.27	0.15	2.26
<i>Economic-political variables (M_{ht})</i>										
Interest	6.38	1.67	7.60	0.81	7.63	0.80	5.36	1.65	5.49	1.61
Trend before quota	-3.35	4.25	-6.05	3.20	-6.22	3.09	-0.04	0.22	-0.04	0.25
Trend during quota	5.28	7.78	0.00	0.00	0.00	0.00	10.7	7.29	9.69	7.33
<i>Dependent variable (Y_{ht})</i>										
Time period			2.24	1.75	2.09	1.61	3.35	3.43	3.27	3.44

3.4 Empirical model

In this section we present an empirical model explaining the time period between two changes in land used for milk production and the direction of land use change. The sequence of changes in land used for milk production is illustrated for a hypothetical farm in figure 3.2. Entry of the farm in the dataset can take place in the first year of the dataset or during the observation period. The hypothetical farm in figure 3.2 enters at the first year of the dataset in 1971. The time period until the first change in land use is not observed because we do not know the time period between this and its previous change. With the next change in land used for milk production in 1976 we observe Y_{h76}^{inc} . At the year of change (1976) dairy land has increased. The second change in land used for milk production takes place in 1982 where a decrease in land is observed (Y_{h82}^{dec}). The sequence of land use changes continues until the farm decides to quit farming or at the end of the observation period (2011). The hypothetical farm in figure 3.2 remains in the dataset until 2011, but is last observed at the year of its most recent land use change, 2009.

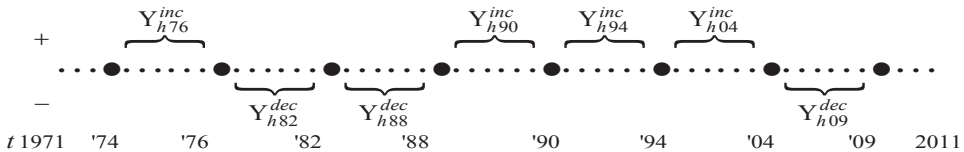


Figure 3.2: Sequence of changes in land used for milk production for a hypothetical farm.

3.4.1 Growth in dairy land and time period

For a farm with multiple changes in land used for milk production we observe the time periods between two changes of at least 10% of land used for milk production. The time period is represented by Y_{ht}^{inc} and Y_{ht}^{dec} and is defined as the number of years between two changes

for farm h in year t , which can either be an increase (Y_{ht}^{inc}) or a decrease (Y_{ht}^{dec}) in dairy land. Hence, for each year t all farms that experience either an increase or decrease in land use are considered and for each farm the number of years from the last change until t is measured as the dependent variable. We model these periods using the following equations:

$$Y_{ht}^{inc} = \alpha_h^{inc} + \varphi^{inc} K_{ht} + \delta^{inc} Z_{ht} + \rho^{inc} Q_{ht} + \phi^{inc} M_{ht} + u_{ht}^{inc}, \quad (4a)$$

for an increase in land use, and

$$Y_{ht}^{dec} = \alpha_h^{dec} + \varphi^{dec} K_{ht} + \delta^{dec} Z_{ht} + \rho^{dec} Q_{ht} + \phi^{dec} M_{ht} + u_{ht}^{dec}, \quad (4b)$$

for a decrease in land use.

Here α_h^{inc} and α_h^{dec} capture unobserved time invariant characteristics of farm h influencing the time period in case of an increase and decrease respectively. K_{ht} represents the variables related to the presence of the milk quota system for farm h at year t , φ^{inc} and φ^{dec} represent the vectors of coefficients of these milk-quota related variables. Z_{ht} contains the strictly exogenous explanatory variables on the socio-economic characteristics for farm h at year t . δ^{inc} and δ^{dec} represent the vectors of coefficients for the strictly exogenous socio-economic variables for farm h at year t . Q_{ht} represents the vector of variables related to farm income and ρ^{inc} and ρ^{dec} represent the vectors of coefficients for these variables. M_{ht} represents the vector of economic-political variables and ϕ^{inc} and ϕ^{dec} represent the vector of coefficients for these variables. u_{ht}^{inc} and u_{ht}^{dec} represent the error terms.

3.4.2 Estimation method

The two equations representing the time periods are estimated using a duration model. Duration models analyse the impact of factors that have a significant effect on the length of

time between two events (see e.g. Verbeek (2008)). A duration starts at the beginning of a previous change and ends at the beginning of a new change.

A number of decisions have to be made in the specification of a duration model. We estimate a multistate-multi-episode process where each farm has the possibility to either increase or decrease the land used for milk production (multistate) as often as the number of years during which it is under observation (multi-episode) (Blossfeld *et al.*, 2007). We estimate the duration model twice; once for increases and once for decreases in dairy land use.

The statistic reason for duration analysis is that it provides a solution to the otherwise violated normality assumption of Ordinary Least Squares (OLS), meaning that time, conditional on the explanatory variables, is assumed to follow a normal distribution (Cleves *et al.*, 2008). This assumption is unrealistic because the distribution of the equation for the time period is non-symmetric. The time period is always positive and not constant over time. Moreover, OLS does not correct for right censored data. This means that farms may still be in the process of land use change at the end of the observation period (Cleves *et al.*, 2008).

Parametric duration analysis allows us to handle the specific features of our data; time-varying explanatory variables, delayed entry, gaps, and right censoring. Where nonparametric and semi-parametric models compare different farms at times of land use changes, parametric models use probabilities that define the land use changes over the whole time period, given the information of the farm in the explanatory variables. Hence, a parametric model exploits all information on the explanatory variables.

Central to duration models is the hazard rate; the probability that either Y_{ht}^{inc} or Y_{ht}^{dec} at time t is observed. With parametric models, the shape of the hazard rate is allowed to vary over time, meaning that the pace of change in dairy land use may increase or decrease over time. Different types of parametric models inhabit different shapes for the hazard rate, the so-called time dependency. Specifying the correct one is therefore of importance with regard to potential misspecification of the influence of explanatory variables. Within parametric

models, there are 5 common distributions, namely the exponential, weibull, gompertz, log-normal and log-logistic. According to our theoretical framework the profit increasing potential achieved by growth of size will decrease the time period. However, the existence of a quota regime undermines this process. Following the introduction of the quota regime, the hazard rate will therefore increase as time passes. In this study, we assume that the model follows a non-monotonic hazard, where the time period decreases before the introduction of the quota, and increases after the introduction of the quota. Only the log-normal and log-logistic model use this distribution for the hazard; we choose the log-logistic model.

With parametric models the hazard rate is allowed to change with time and with the farm and time specific covariates (Towe *et al.*, 2008):

$$h(t, \mathbf{x}) = \lim_{\Delta t \rightarrow 0} \frac{\Pr(t \leq T \leq t + \Delta t | T \geq t, \mathbf{x})}{\Delta t} \quad (5)$$

where $h(t, \mathbf{x})$ is the probability that land use change occurs between t and $t + \Delta t$ and T is the moment at which an increase or decrease in land used for milk production occurs. For the log-logistic model, the hazard rate is specified as (Blossfeld *et al.*, 2007):

$$h(t, \mathbf{x}) = \frac{\lambda^\gamma t^{\frac{1}{\gamma} \left[\left(\frac{1}{\gamma} \right) - 1 \right]}}{\gamma \left[1 + (\lambda t)^{\frac{1}{\gamma}} \right]} \quad \text{with } \lambda_i = e^{-(\mathbf{x}_i \beta_i)} \quad (6)$$

where λ gives information on the location of the explanatory variables and γ is the slope parameter. If $\gamma < 1$ the hazard rate first increases and then decreases, if $\gamma \geq 1$ the hazard rate decreases.

The log-logistic model is estimated using the AFT (Accelerated Failure Time) metric, which assumes a linear relationship between the log of t_h and the characteristics of the farms \mathbf{x} :

$$\ln(t) = \mathbf{x}\boldsymbol{\beta} + \varepsilon \quad (7)$$

where ε_j is distributed normally with mean 0 and standard deviation $\pi\gamma/\sqrt{3}$ (Cleves *et al.*, 2008). This means that we estimate the time period, depending on its explanatory variables, using maximum likelihood (Blossfeld *et al.*, 2007).

The duration analysis has been executed using standard features in STATA 12/SE². Because we allow for time-varying covariates and multiple changes in land use per farm, we need to assume that the observations within each farm are not independent. We therefore specify clusters within each using STATA's *vce(robust)* option to avoid misspecification of the standard errors. To check for the robustness of the distribution, we compared results of the log-logistic distribution with those of other distributions for which the AFT metric was allowed (exponential, weibull, lognormal and gamma model). These showed little variation in the signs and significance of covariates between distributions. Only for the exponential distribution and increases in land use changes in sign and significance were observed. However, this distribution is the least suited for our analysis.

3.5 Results

In this chapter, the time period and the direction between two changes in land used for milk production on dairy farms before, during and towards the abolition of milk quota are analysed. We define change as a decrease or increase of at least 10% in land used for milk production on a dairy farm.

² The duration analysis has been executed in three main steps (STATA, 2013). First, we convert the time series data into time-period data using STATA's command *snapspan: snapspan [instantaneous variables], gen(year_org) replace*. Second, we declare our dataset to be duration data using *stset: stset year_fin, origin(time year_beg) id(farm) failure(i_land_10==1) exit(time .) time0(year_beg)*. Third, we estimate the duration analysis using STATA's *streg* command: *streg [varlist], distribution(loglogistic) vce(robust)*.

3.5.1 Model results

Table 3.4 shows the regression results and the marginal effects at the means for the effect of the covariates on the time periods for increases and decreases in land use separately. The logged time period increases with a positive coefficient and decreases with a negative coefficient. When exponentiated, the coefficients report the ratio by which the dependent variable changes for a one unit increase in the explanatory variable. Our log-logistic models found log pseudo-likelihood values of -68746.78 for increases and -96462.923 for decreases in land use. Using the likelihood ratio test, the null hypothesis of no significant contribution of at least one of the explanatory variables to the model fit can be rejected at the 1% level. The log-logistic models for increases and decreases in land use both show $\gamma < 1$, meaning that the log-logistic hazard first increases and then decreases, as we hypothesised in the previous section.

3.5.2 Regression results

Variables used to analyse the time period equations consist of variables related to the presence of milk quota (K_{ht}), socio-economic characteristics (Z_{ht}), farm income (Q_{ht}) and the economic-political situation (M_{ht}).

Variables related to the presence of milk quota (K_{ht}) consist of a dummy indicating whether there is a quota regime, a dummy explaining the adjustment to the quota regime, and a trend as of 2003 representing the transition towards quota abolition. There is a positive effect of the presence of a quota regime and a negative effect of the transition towards quota abolition on the time period towards an increase in land use. For the time period towards a decrease in land use both the presence of the quota regime and the transition period have a negative effect. For the adjustment to the quota regime a significant and negative effect is found only for increases in land use. Table 3.3 shows that towards quota abolition, more dynamics in land

use change are observed, with marginal effects of -0.44 years for increases and -1.39 years for decreases respectively. Together with the longer time periods during the quota regime for increases in land use, this indicates that quota hamper the pace of change in land used for milk production for farms who want to increase milk production. This is in line with previous research that indicated that the existence of a quota regime delays the pace of farm structural change (Breustedt and Glauben, 2007; Piet *et al.*, 2012). However, this is not the case for farmers decreasing their land, since they also experience shorter time periods during the quota regime. A possible explanation may be that the ability to sell quota makes their (partial) exit from dairy farming easier.

Socio-economic characteristics (Z_{it}) consist of age and age squared of the farm operator, whether the farm operator works full-time or part-time on the farm and whether he followed an agricultural education and his level of education, whether he has a successor and an interaction term between age and successor.

With respect to the time period between two changes in land use, we would expect a longer time period for older farm operators towards both increases and decreases in land use. The older the farm operator, the lower his opportunity costs and the less likely he is to alter his land use. However, when the farm operator is close to retirement the time period may decrease due to life cycle patterns (Weiss, 1999; Gale, 2003). There is a positive and significant sign for age and a negative and significant sign for age squared of the farm operator for both the increasing and the decreasing time period equation. This is in line with the results of Francksen *et al.* (2012) who suggest that younger farmers are more willing to take risks in order to improve their competitive position.

We find a significant and positive effect of 0.59 and 1.06 years for full-time labour involvement of the farm operator for respectively increases and decreases in land use. This means that the more involved the farm operator is, the less likely he is to change his land use. A possible

explanation may be that farm operators who work full-time on their farm have less time available to make on-farm changes.

Whether the farm operator followed an agricultural education shows a significant and positive effect for both increases and decreases in land use. However, the marginal effect is larger for decreases (0.97 years) than for increases in land use (0.60 years). This may imply a certain locked-in effect; being agriculturally educated may limit the possibilities to work outside, and therefore to adjust land use. The level of education of the farm operator shortens the time period in case of increases in land use by 0.07 years but increases the time period in case of decreases in land use by 0.12 years. The level of education is likely to be correlated with management skills, and therefore improves the position of these farmers.

Having a successor shortens the time period for increases in dairy land use by 1.62 years, but increases the time period by 0.75 years for decreases in land use. This implies a higher pace of expansion and less reduction for farms with a successor. This is as expected, because these are the farms that want to improve their position by specializing and increasing their dairy land. Variables related to the income of the farm (Q_{it}) include the change in the national average milk production per cow, the change in total labour and the change in the national average milk price with respect to the previous year, the total hectares of land to represent farm size, the share of land used for milk production to represent specialization and the number of cows right after the previous change.

The yearly change in the average production per cow was used as a measure of productivity growth. An increase of 100 kilograms in milk production per cow leads to a longer time period for both increases (0.21 years) and decreases (0.12 years). Francksen *et al.* (2012) found a similar effect for farms with a high quota growth. Milk quota may serve as a restricting factor because the productivity growth may induce small growth that can be made without purchasing quota; needing fewer cows and less land to maximize a farmer's quota amount. However, more productive cows have higher feed, and therefore land, requirements for roughage and

grazing. Therefore, a change in land caused by an increase in average production per cow depends on the ratio of the decrease in cows versus the increase in land required per cow.

The yearly change in average milk price causes the period of both increases and decreases in land use to shorten. For increases in land, a higher milk price improves liquidity and therefore accelerates land use change. Although at a slower pace, we find the same sign for decreases in land. It may be that a milk price increase leads to an increase in the shadow price of land; however, with different proportions for different farms. This leads farmers with a relatively small increase to decrease their land used for milk production. The share of fodder land increases the time period for increases in land use. This may be because a larger share of fodder land implies less on-farm land that can be easily converted, leading to larger adaptation costs.

For increases in dairy land use the change in labour shows a negative and significant effect, while for decreases in dairy land use the change in labour shows a positive effect. This is as expected; increasing land for dairy production requires more on-farm labour. For the change in the number of cows, we find that the size of the dairy herd after the previous change leads to a shorter time period of 0.04 years for increases in land and a longer time period of 0.02 years for decreases in land use. Due to the nitrogen regulations in the Netherlands, a change in dairy herd demands a corresponding change in land for dairy production.

The total amount of land measured in hectares on the farm shows a very small positive effect for increases in land use and a small negative effect for decreases in land use. This may have to do with our definition of growth as relative to the total land used for dairy farming. With the same percentage, the absolute number of hectares of change is lower for smaller farms than for larger farms.

Table 3.3: Regression results and marginal effects at means for increases and decreases

Variable	Increases				Decreases			
	coeff	sign	ME	sign	coeff	sign	ME	Sign
<i>Quota variables (K_{it})</i>								
Quota	0.192	***	1.140	***	-0.267	***	-2.171	***
Adjustment	-0.125	***	-0.722	***	-0.006		-0.047	
Transition	-0.073	***	-0.443	***	-0.177	***	-1.386	***
<i>Socio-economic characteristics (Z_{it})</i>								
Age	0.037	***	0.047	***	0.029	***	0.012	***
Age squared	-0.000	***			-0.000	***		
Fulltime operator	0.101	***	0.585	***	0.145	***	1.060	***
Agricultural education	0.100	***	0.595	***	0.128	***	0.969	***
Occupational education	-0.012	**	-0.071	**	0.015	**	0.121	**
<i>Continuity of the farm</i>								
Successor	0.101		-1.616	***	0.476	**	0.753	***
Age x successor	-0.007	*			-0.007	**		
<i>Farm income variables (Q_{it})</i>								
Share of fodder land	0.519	***	3.153	***	0.006		0.050	
Production growth	0.034	***	0.207	***	0.016	***	0.124	***
Change in labour	-0.019	***	-0.114	***	0.031	***	0.241	***
Total ha land	0.007	***	0.043	***	-0.007	***	-0.057	***
Herd at previous change	-0.007	***	-0.041	***	0.003	***	0.022	***
Change in milk price	-0.026	***	-0.159	***	-0.016	***	-0.123	***
<i>Economic-political variables (M_{it})</i>								
Interest	0.035	***	0.215	***	0.014	***	0.110	***
Trend before quota	0.157	***	0.951	***	0.154	***	1.207	***
Trend during quota	-0.026	***	-0.159	***	0.020	***	0.159	***
Constant	0.398	*			1.195	***		
Gamma	0.305				0.351			

Note: ***, **, and * denote significance at the 1, 5 and 10 per cent levels respectively.

Economic-political variables (M_{ht}) are represented by the interest rate and a split time trend capturing structural developments around the introduction of the milk quota. The interest rate lengthens the time period for both increases and decreases in dairy land use with 0.22 and 0.11 years respectively. As suggested in the theoretical model, a higher interest rate implies less liquidity, larger adjustment costs, and therefore decelerates land use change. For farms increasing in land use a clear break is observed around quota introduction, making the time period longer before, and shorter after quota introduction. For decreases in land use both trends make the time period longer, although with very different magnitudes; 1.21 years before and 0.16 years after quota introduction.

3.5.3 Sensitivity analysis

To explore the consequences of our definition of land use change we performed six sensitivity analyses. We simulated changes of 5%, 30% and 50% and changes of at least 4, 10 and 20 hectares of land. Four hectares is on average equal to a 10% change in land used for milk production. The calculated marginal effects of the sensitivity analyses are found in Table 3.4. The results of the sensitivity analyses show that for most variables, no changes in both sign and significance are observed when the definition of change is altered. In general, we can see that the marginal effects of the covariates rise when the definition of land use change is set at a higher percentage. For some variables, a change in sign and significance is however observed. For increases in land use, the variables occupational education and trend during the milk quota regime change from shorter to longer time periods. For decreases in land use, the variables age and interest rate change from longer to shorter time periods. Larger percentages of decrease may depend on whether the farmer is close to retirement, accelerating large decreases around this age. An increase in interest rate may decrease the liquidity position of a farm, which may especially be of concern when larger percentages of land are involved.

Table 3.4: Sensitivity analysis of 5%, 30%, 50% and 4, 10 and 20 ha land use change

	Time interval increases						Time interval decreases					
	5%	30%	50%	4ha	10ha	20ha	5%	30%	50%	4ha	10ha	20ha
<i>Quota variables (K_{it})</i>												
Quota	1.2*	1.5*	1.5*	2.0*	2.7*	3.9*	-0.6*	-5.3*	-7.3*	-2.9*	-4.7*	-1.5
Adjustment	-0.8*	-0.6*	-0.4*	-0.7*	-1.1*	-0.2	-0.5*	1.1*	1.7*	0.3*	1.6*	3.4
Transition	0.5*	-0.4*	-0.4*	-0.7*	-0.3*	0.1	-0.1	-0.8*	-0.6*	-1.4*	-1.3*	-0.0
<i>Socio-economic characteristics (Z_{it})</i>												
Age	0.0*	0.1*	0.1*	0.1*	0.1*	0.0	0.0*	-0.0*	-0.0*	0.0*	0.1*	0.1*
Fulltime	0.5*	1.5*	1.8*	0.6*	1.3*	0.8	0.7*	2.2*	2.7*	1.1*	2.2*	1.0
Agr educ	0.5*	0.6*	0.7*	0.6*	0.5*	0.5	0.7*	1.6*	2.4*	1.2*	1.9*	2.4*
Occ educ	-0.2*	0.2*	0.1	0.1	0.6*	0.9*	-0.1*	0.9*	1.5*	0.4*	2.0*	3.6*
<i>Continuity of the farm</i>												
Successor	-0.6*	-1.2*	-0.1	-1.9*	-1.1*	-0.7	0.7*	3.0*	4.3*	0.7*	3.9*	5.2*
<i>Farm income variables (Q_{it})</i>												
Share fodder	1.8*	4.2*	5.3*	4.3*	5.5*	7.4*	-0.3*	4.5*	10.4*	-0.8*	1.1	1.2
Production growth	0.3*	0.1*	0.0	0.1*	0.0	0.0	0.2*	0.0	-0.0	0.0	-0.2*	-0.2
Change in labour	-0.1*	-0.3*	-0.3*	-0.1*	-0.1	-0.0	0.2*	0.8*	1.3*	0.3*	0.6*	0.2
Total ha land	0.0*	0.1*	0.1*	0.0*	-0.0	0.0	-0.0*	0.0	0.1*	-0.1*	-0.2*	-0.1*
Herd at previous change	-0.0*	-0.1*	-0.1*	-0.1*	-0.0*	-0.0*	0.0*	0.0	-0.1*	0.0*	-0.01	0.0
Change in milk price	-0.3*	-0.0	-0.0	-0.0	0.0	-0.0	-0.3*	-0.1*	-0.1	-0.1*	-0.3*	-0.4
<i>Economic-political variables (M_{it})</i>												
Interest	0.6*	0.0	0.0	0.0	0.0	-0.1	0.5*	-0.1	-0.2*	-0.0	-0.2*	-0.2
Trend before	0.8*	1.2*	1.3*	0.9*	1.1*	1.1*	1.0*	2.0*	2.9*	1.3*	1.9*	1.5*
Trend during	-0.4*	0.1*	0.3*	-0.1*	0.0*	-0.1*	-0.2*	0.7*	1.0*	0.3*	0.7*	0.8*

Note: * denotes significance at the 5 per cent level at least.

3.6 Discussion and Conclusions

Milk quota could be seen as a farmer's most scarce production factor; in order to increase production, a farmer first has to buy quota rights. In the absence of quota, land is the most scarce production factor; a farmer needs enough land for roughage production and grazing but also to comply with the nitrate regulations, expressed per hectare of land, if he wants to increase his production. This makes analysing time and the length of time periods between changes in the use of land relevant for both farms and policy makers. The purpose of this chapter is therefore to analyse the time period between two changes in land used for milk production on dairy farms and the direction of land use change over a period before, during and towards the abolition of milk quota. We use longitudinal data from the farm structure survey of the Netherlands covering the period between 1971 and 2011. We hypothesize that land use changes involve adaptation costs hampering land dynamics. These adaptation costs may be related to policy (in our case milk quota), socio-economic, farm income and economic-political variables.

Quota variables representing the presence of the quota regime and the transition towards abolition of the quotas show that quotas hamper the pace of change for expansion in land used for milk production. The time period for increases in land use is enlarged during the quota regime and shortened towards the abolition of quota. The time period for decreases in land use is shortened during the quota regime and towards the abolition of quota. The longer time period for increases in land use shows that milk quota hamper farm dynamics. The shorter time period for decreasing land use may indicate that reducing milk production is easier. This is probably due to the fact that milk quotas can be leased-out or sold. The shorter time period towards quota abolition shows that more farm dynamics can be expected as a result of the possibility to produce more milk.

When milk quotas are abolished, nitrate regulations, expressed per hectare of land, may become the limiting factor for milk production. This directly connects changes in dairy land

use to changes to milk and roughage production. However, a farmer who decreases his milk production may not directly opt to convert or sell his land. This chapter therefore looks at land use changes in light of changes in milk production. A farmer who wants to increase his milk production may also have the option to buy compound feed and to make use of manure processing. Further research is necessary to investigate to what extent the increased dynamics from quota abolition will be offset by the nitrate regulations.

The farm's decision to increase or decrease land used for milk production is largely determined by characteristics of the farm operator such as age, full-time employment, education and whether he has a successor. We find that younger farm operators with a higher education level, who do not work full-time on the farm, have a successor and do not yet spend a large portion of their total land to milk production exhibit highest dynamics in land use change in favour of milk production. On the contrary, farmers with a low education level and without a successor exhibit highest dynamics in land use change away from milk production. It may be that these types of farms face higher adaptation costs for land use change. The effects of age and occupational education become more proficient when land use change is defined with a larger amount of increases or decreases.

Our study complements the existing literature by looking at the interrelations and non-linear nature between land use change and milk quotas using a duration model. Although previous studies mainly focused on farm growth and entry/exit decisions of farms, we find results that are closely related. Weiss (1999), Gale (2003) and Breustedt and Glauben (2007) all found that farm exit is accelerated when the farm operator is older. Glauben *et al.* (2006) add that the exit rate further increases when the farm operator does not have a successor and Weiss (1999) adds that the exit rate decreases if the farm operator is agriculturally educated. The results of the existing literature are more controversial on the influence of full-time farming. Full-time farming increases the probability of farm exit according to Glauben *et al.* (2006) and Breustedt and Glauben (2007) but reduces farm structural change according to Weiss (1999).

A number of possible caveats can however be mentioned. First, our approach only looks at the time period between land use changes on farms, and is thereby not able to explain farm structural change. Second, following the 2003 Mid-Term Review, single farm payments were introduced to compensate for the decrease in intervention prices. Our model does not account for these, and other, policy measures; potentially leading to an overestimation of the milk quota effects. In order to overcome at least part of the overestimation, we included a split time-trend to capture systematic changes in the economic conditions of farmers. Following the course of the CAP, the first part of the split time trend may represent the on-going price and income support, whereas the second part may represent the on-going liberalization. Despite these caveats, employing a duration analysis to the pace of on-farm land use changes leads to more insights in the dynamics of the dairy sector.

CHAPTER 4. EXPLAINING FARMLAND PRICES: THERE IS MORE TO IT THAN AGRICULTURE¹

Abstract

Farmland prices can be explained by the maximum bid price of the buyer, determined by the expected revenue generated from the acquired land as well as the local and general economic effects. General effects consist of the economic situation and land regulations, whereas local effects consist of rival (agricultural) bidders and potential future more valuable use of the land (option value). The objective of this paper is to explain farmland prices in the Netherlands, and more specifically to analyse the effect of the financial crisis on the land market price. We distinguish four categories influencing the price of land: (i) the direct influence via the returns from land, (ii) institutional regulations, (iii) the spatial environment and (iv) local market conditions. Two periods are compared to distinguish the effect of the crisis on the agricultural land market. Using a unique dataset comprising individual transactions in the Netherlands between 2004 and 2011 we find that all categories significantly influence land prices. Moreover, financial crisis leads to a decline in the effects of local market conditions, but the announcement of milk quota abolition in 2008 has led to an increase in the effects of the spatial environment between the first and the second period.

¹ Paper by Esther Boere, Jack Peerlings, Stijn Reinhard, and Tom Kuhlman, submitted to a peer-reviewed journal.

4.1 Introduction

In the Netherlands, farmland prices are affected by the general economic situation despite its strict zoning policies. If more land is needed for infrastructure, housing and industrial areas, pressure for farmland conversion rises. Farmers who subsequently have to sell their land but decide to continue farming (based upon tax exemptions) need to buy farmland somewhere else. This makes the remaining farmland scarcer, and therefore leads to higher farmland prices. Moreover, the general economic situation affects several factors like the interest rate, demography, demand for food, exchange rate etc. that may influence farmland prices. In 2008 an economic crisis hit the Netherlands, like the rest of the world. This gives a unique opportunity to analyse the effect on farmland prices.

Many studies have tried to characterize the factors that together compose the price of farmland by characterizing two different channels. The first channel is usually composed of the net returns to land, the Net Present Value (NPV). The value of farmland for the buyer is usually derived by taking the NPV of the future stream of income generated from the land. Income generated depends on factors such as input and output prices and usually includes government subsidies that have a direct effect on the price of land, of which direct payments are the most well-known (Weersink *et al.*, 1999; Ciaian and Kancs, 2012; Latruffe and Le Mouel, 2009). Agricultural policies, especially direct payments, will enhance farm incomes and will lead to a capitalization in the price of land (Clark *et al.*, 2003; Goodwin and Ortalo-Magne, 1992; Latruffe and Le Mouel, 2009). Under the assumption of complete information, the maximum bid price however does not have to be paid if the farmer's potential rivals have a lower maximum bid price for a certain parcel. The second channel involves other factors that influence the price of farmland, but do not directly affect the (current) returns to land. They provide an additional component that may be added or subtracted from the NPV of land to get close to explaining the price of farmland. These include other policies such as zoning laws (Henneberry and Barrows, 1990) and nearby characteristics such as residential and

nature influences (Borchers and Duke, 2012; Plantinga *et al.*, 2002; Livanis *et al.*, 2006; Shi *et al.*, 1997; Cavailhes and Wavresky, 2003). Zoning laws restrict the location and type of land use in a certain area by posing rules and regulations on the use of a parcel of land. Although the Netherlands has a zoning system, an option value can exist in anticipation of change to the agricultural zoning policy, to allow residential buildings or industry. As houses and firms have a higher maximum bid price, buyers can speculate that the value of the agricultural land will increase in the future. This phenomenon makes a price above the maximum agricultural bid price possible (Plantinga *et al.*, 2002). With a larger demand from houses and firms during high economic conjecture, the general economic situation strongly influences the option value of farmland.

All of these studies indicate that both farm income and non-farm income factors are important; however, they have not been able to complete the “farmland valuation puzzle” (Power and Turvey, 2010). This study does not aim to do so either, but does provide a more complete picture by including both the general and the local economic situation. The objective of this paper is to explain farmland prices in the Netherlands and to analyse the effect of the financial crisis on the land market price, controlling for other factors explaining farm land prices. To our understanding, this paper provides a first comprehensive analysis general and local economic factors influencing the price of farmland, accounting for both space and time, at the farm level.

In this study we divide the factors determining farmland prices in four categories. In line with the existing literature, the first category consists of factors directly determining the expected net revenue obtained from farming. The second category consists of institutional regulations (e.g. inheritance regulations) that restrict the kind of ownership of the land and transactions. These institutional regulations impose costs for buyers and sellers of the land (Ay and Latruffe, 2013; Just and Miranowski, 1993). The third category consists of factors relating to the spatial environment in which the farmer interacts on the market. Spatial policies play a

role by allocating claims on land of different sectors (i.e. zoning) (Ay and Latruffe, 2013; Ciaian *et al.*, 2012; Jaeger *et al.*, 2012). The fourth and final category consists of local market conditions that determine the option value of land. The option value is likely to be influenced by location characteristics such as urban sprawl (Shi *et al.*, 1997) and demographic variables such as population density (Devadoss and Manchu, 2007; Livanis *et al.*, 2006).

We restrict ourselves to transactions where the buyer of land practices land-based agriculture (i.e. other than greenhouse horticulture and non-grazing livestock) and include only transactions that are bought by farmers and therefore do not include land that is leased. Actual land prices originate from a unique dataset comprising individual land transactions in the Netherlands covering the period between 2004 and 2011. By linking land transactions to the expected net revenue of the average farm of the same type as the buying farm we are able to analyse a large set of land transactions without the need for data on all factors determining income such as input and output prices and the endowment of capital for all buying farms. Moreover, we account for the demand and supply in the agricultural neighbourhood using a spatial lag model.

In the next section, we develop a framework to analyse land prices using the four aforementioned categories. Section 4.3 presents the data and descriptive statistics. The estimation procedure of the four categories, using spatial econometric techniques, is explained in section 4.4. Results are presented in section 4.5 while section 4.6 concludes.

4.2 Theoretical Framework

In this study, we propose a framework that consists of four categories: (i) The revenue obtained from farming the land. (ii) Institutional and transaction regulations (e.g. inheritance regulations) that may pose additional costs on the land, e.g. in case it is not fully owned. (iii) The spatial environment in which the farmer interacts on the land market. If more buyers than sellers are in the market, the maximum bid price of the actual buyer will be higher than in the

reversed situation. This is determined by the competition on the land market. (iv) The option value of the land. If buyers expect in the future a substitution of a more profitable land use for the current agricultural use, they will offer a higher price for the land. In this section, we develop a model in order to explain these four different categories.

4.2.1 *First category: Revenue obtained from farmland*

Following standard microeconomic theory, future stream of income generated from the land, including other benefits derived from the land and while accounting for additional costs related to investments, should equal the price of land (Lence and Mishra, 2003). Most papers analysing land values use an income approach, where the value of land is the discounted sum of expected future cash flows, i.e. the NPV of farmland (see amongst others Weersink *et al.*, 1999; Goodwin *et al.*, 2003, Lence and Mishra, 2003 and Duvivier and de Frahan, 2005). This entails all revenues obtained from agricultural activities on the land. Besides the revenues obtained from productive use of land, the producer may obtain revenues from e.g. government payments. Many studies showed the influence of government payments on the capitalization of land prices, and direct payments are generally listed as the main one (see Latruffe and Le Mouël, 2009) for an overview).

In our analysis we do not have farm-specific data to calculate the NPV of the buying farm. We do however know the buyer's farm type, and have data on the average net revenue of each distinguished farm type (e.g. milk production, arable production, etc.). Discounting the expected future returns of agricultural land use will then not increase the explanatory power of the model. We will therefore use the expected net real market-based return and the net government-based return per farm type per hectare of land (see the next section for its exact calculation). Both the net revenue of the newly acquired land and the average net revenue of the buying farm may deviate from the average of their farm type. For instance, if the successor joins the farm this may result in excess labour per hectare, thereby increasing the returns of

additional hectares. This farm specific revenue of the acquired land can be captured by the operator's age. In order to expand operations, a farmer needs to have a long-term perspective on using the newly acquired land. Age may therefore capture opportunity costs as well as farmer's life-time working cycle (Breustedt and Habermann, 2011). Based on the amount of land and labour currently available, a farmer might be in a better position to acquire collateral for a new loan, needed for the acquisition of new land. The share of land in total production factors differs between farm types. A higher degree of substitutability may lead to a reduction of the price the farmer is willing to pay for additional land, which in turn may lead to larger effects of subsidies on land for land based than for non-land based sectors (Latruffe and Le Moel, 2009).

Differences in the maximum bid-price between the buying and the average farmer can be caused by farm-specific factors making the farm-specific revenue deviate from the farm type average revenue, as well as other non-income generating factors. We focus on three of these non-income generating factors in the other categories.

4.2.2 *Second category: Institutional regulations*

As reflected upon in the introduction, land institutional and transaction regulations affect the agricultural land market. Governments often impose ownership regulations on farmland, such as ownership with or without leasehold. These regulations result from lobbying activities by interest groups, causing ownership regulations to be endogenous to the price of land (Ferguson *et al.*, 2006). Land may be family owned, or privately owned with or without lease. These different regulations further undermine the competitive market for land transactions. The supply of land is limited and even when available, institutional relations, such as farming families living in the same village, may cause land not to end up with the highest bidder (Breustedt and Habermann, 2011).

4.2.3 *Third category: The spatial environment in which the farmer interacts*

The degree of competition among farmers to buy the land is of importance in explaining the difference between the actual price paid for farmland and its expected revenue. Because farmers are only looking for farmland that is in close proximity to their current location, land markets get fragmented, resulting in locally disaggregated markets. A very competitive land market will force farmers to offer their maximum bid price to acquire the land. In a less competitive market the farmer may buy the land with a discount on the maximum bid price. Here we discuss the main factor that influences the segregation between local land markets and help explain the degree of competition within them: the geographical region.

Within the agricultural sector, activities in the Netherlands still largely follow the conventional model of Von Thünen with high-value agriculture using large transportation costs, such as greenhouse farming, located in urban areas and low-value agriculture, such as arable farming, located in the relatively rural areas. Strong zoning policies usually distinguish agriculture in the urbanized West into two types: greenhouse farming and land-based farming, mainly dairy farming (Alterman, 1997). With dairy farmers increasingly buying land of arable farmers, this geographical differentiation has however declined in importance.

This segregation of farm types by geographical region is inherent to its differentiation in soil type. The soil type determines the productive capacity for different land uses. Land is heterogeneous, making some types of land are more productive than others. This matters to some types of farms more than to others. Some soil types (e.g. peat) are only suitable for extensive dairy farming, while sandy soils can be used efficiently by various farm types. Hence, the physical location determines not only yield (part of category 1), but also the farm type that enters the market for the land (category 2). Especially bulb growers and certain arable farm types such as seed potato farms may select their buying location based on the soil type. In the Netherlands, this can be further observed by the geographical differentiation in land-based agriculture between arable farming and grazing livestock (mainly dairy farming),

with arable farming mostly located in the South-West and North-East (provinces of Zeeland, Flevoland and Groningen) and dairy farming mostly located in the North-West and Mid-East (provinces of Friesland, Utrecht, Gelderland, Overijssel, and Friesland).

4.2.4 Fourth category: The option value of the land

Agricultural land markets are influenced by other competing claims on land such as housing and nature. Many countries apply spatial policies that allocate the claims on land of different sectors by zoning. Spatial policies help to concentrate urban areas and to maintain open spaces around them. Hence, they create sub-markets that are differentiated based on their geographical location. Jaeger *et al.* (2012) distinguished three factors that may lead spatial policies to result in either a positive or a negative effect on land price. First, in case zoning policies prevent land from yielding the highest possible shadow price, this may result in a neutral or negative effect. Second, without zoning policies, scarcity will result in a positive effect on the price of land. Third, positive externalities result in a positive effect on land price. In the neighbourhood of a city there is a higher anticipation on future relaxation of the zoning regulation, leading to a larger bid-price of the land. Moreover, in these areas the demand for agricultural products and positive externalities created by agricultural areas may be larger (Devadoss and Manchu, 2007).

Price bubbles that exist in the real estate market (see e.g. Case *et al.*, 2003), may also persist in the market for farmland. These may affect the option value of farmland by posing expectations on future income. Such expectations often go together with economic fluctuations, which can be represented by inflation and anticipation of land development (Just and Miranowski, 1993; Hardie *et al.*, 2001). Evidence of the existence of speculative bubbles in farmland prices has been mixed (Tegene and Kuchler, 1993; Turvey, 2002). This may be because speculative effects are largely dependent on both time and space. Over the past decade, especially time may have had an influence on changing option values of land. The

clear differences before and after the economic crisis observed in the urban land market may also reflect in the rural land market.

4.3 Data and descriptive statistics

As explained in the theoretical framework, different spatial factors, e.g. the distance to cities, the number of buyers and sellers and the concentration of farmers by type, may cause locally fragmented markets for land prices. Moreover, the degree of market fragmentation may depend on time. We therefore divide the Netherlands in two time periods; one before the onset of the financial crisis, from 2004 until 2007; and one after the onset of the financial crisis, from 2008 until 2011. The two periods coincide also with differences in policies caused by the Health Check of 2008. The split in time periods also follows from the fact that it is computationally not possible to estimate a weight matrix consisting of 20,000 observations.

Data used in this study consists of three different databases, all considering the time period between 2004 and 2011 for the Netherlands. The price of land and institutional and transaction regulations are obtained from the land transactions database of LEI, the Dutch Agricultural Economics Research Institute. These transactions include also transfers between generations. We selected only transactions comprising at least 1 hectare with a price per hectare between €15,000 and €150,000. Extreme values above or below this range are likely to represent unobservable site characteristics and therefore do not reflect the price per hectare of land accurately. We converted the price of land from nominal to real prices using an index for agricultural prices with 2010 as the base year (LEI, 2014c).

Revenue directly obtained from the land, characteristics related to the farm type and characteristics related to the buying farm all help to determine revenue generated on-farm (category 1). The expected net revenue of the buying farm type per hectare is obtained from the FADN, and serves as a proxy for the marginal profit of an additional unit of land. We take

the net revenues of the buying instead of selling farm to calculate the value of farm land because this may serve as a proxy for the farmer's willingness to pay for the land. We account only for average net revenues per farm type and do not account for legislation such as nitrate regulations. Further, we assume that a farmer who buys an additional hectare of land has already accounted for fixed costs. Net revenues are therefore calculated as the per-hectare average of the total revenues obtained from farming minus variable costs, where revenues exclude earnings from direct payments and variable costs include animal and crop assets and energy but exclude tangible assets, labour and depreciation (LEI, 2014e). Like the land price, we converted the net revenue of land from nominal to real prices using the index of agricultural prices (LEI, 2014c). In order to represent the expected net revenue instead of the actual net revenue, we calculated the moving average of the net revenues, composed of the average of the three years previous to the year in which the transaction took place. The expected average net revenues are calculated for the main land-based farm types in the Netherlands: dairy, arable, starch potato, horticulture, flower bulbs, fruit trees, tree nursery and mixed farms. Starch potato farms are separated from arable farms because they received coupled support over the period of observation. Mixed farms are treated as the rest-category of land-based agriculture, but commonly include a combination of crops and non-dairy pasture. For dairy and arable, the net revenue of land is further distinguished by small, medium and large farms.

Data on direct payments are obtained from the FADN database also (LEI, 2014e). They comprise the average per hectare payment for the type of buying farm in the year the transaction took place. Because the amount of these payments is generally known in advance, we do not take the expected value, but the actual value in the year the parcel of land is bought. The amount of payments is not converted to real terms because government payments are not corrected for inflation.

Variables related to the farm type, farm characteristics and geographical region are obtained from the Farm Structure Survey (FSS) and the transactions database. Farm type includes the share of hectares of land for arable and grassland use, the number of cows and pigs and the number of livestock measured in Livestock Units (LSU) per hectare. LSU is based on livestock feed requirements expressed per hectare of land compared with feed requirements of a dairy cow, and thereby serves as a proxy for the level of manure surplus of the buying farm (Eurostat, 2015). The main livestock groups cows, pigs, sheep, goats and horses are converted to LSU. Farm characteristics represent the size of the buyer in hectares of land, the age and age squared of the buyer, the number of labour units in Full Time Equivalent (FTE) and the number of labour units per hectare as a proxy for on-farm productivity.

Institutional and transaction regulations are taken into account in the second category. They can be further specified into the number of hectares of land transacted and dummies representing whether the seller is a private person, and whether the land is fully or family owned. Alternatively, land transacted may be under leasehold. Regarding the type of buyer and seller, government institutions, municipality, province and national government are characterized as public buyers or sellers, and families and tenants as private buyers or sellers. Other buyers or sellers include nature organizations and banks or insurance companies. The type of ownership can be distinguished into full ownership, ownership with leasehold, family ownership and leasehold.

Geographical region is taken into account in the third category and includes dummies for the provinces, with Limburg as the base province. These capture the geographical location and help capture spatial policies that are often decided upon at the provincial level.

Time and population density compose the fourth category. Population density is measured in terms of inhabitants per 100m² by zip-code and captures the proximity to residential areas. This serves as a proxy for the option value of agricultural land and helps to capture the spillover effects that are generated by residential demand for agricultural land. The time period is

specified two types of dummies, one for each quarter of the year and one for each year in which the transaction took place. Quarterly dummies are aimed to capture seasonal fluctuations, whereas years are aimed to capture changes to the economic and political situation.

Descriptive statistics for all variables can be found in Table 4.1 below. Upon analysing differences between the two periods, it can be observed that while the price of farmland has increased between the first and the second period, the expected revenue had decreased. This provides indication that the difference between farmland price and expected revenue has increased between the two periods. Furthermore, the share of arable land of the buying farm has increased, at the cost of the share of grassland. The shares of transacted land have remained almost equal between provinces. Surprisingly however, less hectare of land are involved in a transaction in the second period compared with the first period. For period 1, the largest share of transacted hectares of land takes place in 2007. For period 2, this is 2008, after which a decrease in land transactions takes place. The relationship between the price of land and the number of transactions can be more clearly observed from figure 4.1: the number of transactions increases until 2007, after which a sharp decrease takes place. The price per hectare of land continues to increase until around 2009, after which it stagnates.

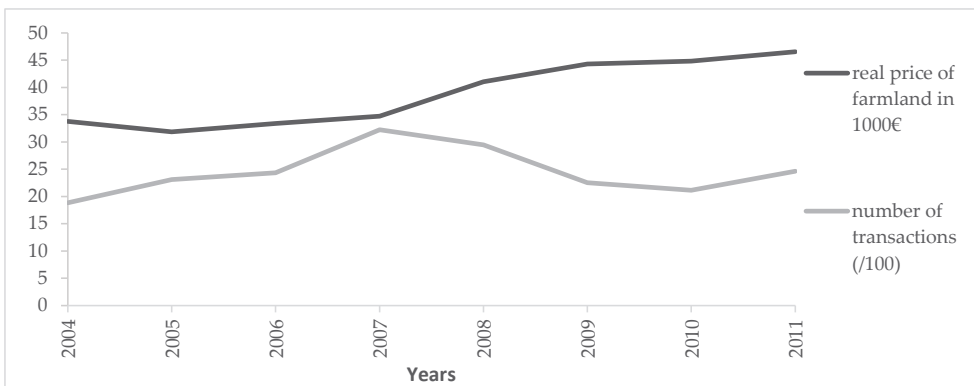


Figure 4.1: Average real price of farmland (€/1000) and number of transactions (/100).

Table 4.1: Descriptive statistics by time period

Variable	Period 1 (obs = 9859)		Period 2 (obs = 9777)	
	mean	std	mean	std
Farmland price	3.50	1.97	4.44	1.96
Category 1: Revenue obtained from farming				
Expected net revenue (1000 €/ha)	5.34	6.89	5.02	5.57
Direct payments (10 €/ha)	6.37	5.00	7.87	5.35
Share arable land	0.29	0.38	0.47	0.39
Share grassland	0.60	0.40	0.46	0.40
Cattle (/10)	8.95	10.11	10.06	11.49
Pigs (/10)	1.24	15.11	3.52	27.33
LSU/ha	2.26	3.19	2.22	2.63
Farm size	52.43	45.19	58.34	51.06
Age	49.86	10.74	50.33	10.29
Age squared	2601.33	1128.17	2639.15	1081.07
Labour in FTE	2.15	2.32	2.31	3.20
Productivity (FTE/ha)	0.09	0.26	0.08	0.20
Category 2: Institutional regulations				
Private seller ^{a)}	0.88		0.90	
Full ownership ^{a)}	0.85		0.88	
Ha transacted	5.91	7.85	5.36	6.76
Category 3: Spatial environment^{a)}				
Groningen	0.06		0.05	
Friesland	0.12		0.12	
Drenthe	0.08		0.09	
Overijssel	0.13		0.13	
Flevoland	0.04		0.02	
Gelderland	0.14		0.15	
Utrecht	0.03		0.03	
Limburg (base)	0.08		0.08	
Noord-Holland	0.05		0.05	
Zuid-Holland	0.06		0.07	
Zeeland	0.06		0.05	
Noord-Brabant	0.15		0.15	
Category 4: Local market conditions^{a)}				
Q1 (base)	0.29		0.31	
Q2	0.27		0.27	
Q3	0.13		0.13	

Q4	0.32		0.29	
2004	0.19			
2005	0.23			
2006 (base period 1)	0.25			
2007	0.33			
2008 (base period 2)			0.30	
2009			0.23	
2010			0.22	
2011			0.25	
Population density (100 m ²)	2.14	3.00	2.16	2.83

^{a)}Dummy variables represent the share of the respective variable in the total sample.

4.4 Empirical Model

In this study we explain the price of farmland with the help of the four categories mentioned in the theoretical framework:

$$P = \alpha + \sigma\mathbf{R} + \gamma\mathbf{I} + \delta\mathbf{G} + \beta\mathbf{T} + \varepsilon, \quad (1)$$

where P is the real price of land per hectare, σ is the vector of coefficients related to the revenue directly obtained from farming, and \mathbf{R} is the vector of variables related to the revenue obtained from farming (category 1). These include the expected net revenue and direct payments per hectare of land, the share in hectares of land per type of farming, the number of cows and pigs, the quantity of labour, the quantity of labour per hectare of land, the size of the buying farm, and the age and age squared of the farm operator. γ is the vector of coefficients related to institutional regulations and \mathbf{I} are the variables related to institutional regulations. These include the type of ownership and variables related to the transaction (category 2). δ is the vector of coefficients related to the spatial environment in which the farmer interacts on the land market and \mathbf{G} are characteristics related to the environment (category 3). These include all provinces of the Netherlands. β is the vector of coefficients related to the option value of the land and \mathbf{T} are characteristics related to the option value of

the land (category 4). These include population density and the time period. ε represents the transaction-specific error term.

Previous studies have noted that the farmland or farm rental price may entail spatial effects that need to be further explained (Patton and McErlean, 2002; Breustedt and Habermann, 2011; Guastella *et al.*, 2013). Spatial effects are observed via spatial dependence. Spatial dependence refers to the interrelationship between two points across space. It can be divided into spatial lag dependence and spatial error dependence, where spatial error dependence refers to the error term and spatial lag dependence refers to the dependent variable (Anselin, 1988). Both spatial error and spatial lag dependence may persist in our data.

Spatial lag dependence may be present by the fact that the price of a parcel affects the price of the parcels in the vicinity directly. Spatial lag dependence would therefore be part of our third category. Patton and McErlean (2003) argue that property owners, prospective buyers, real estate agencies, tax assessors and others base their estimates of values of agricultural land on observed sales in the vicinity. Both Patton and McErlean (2003) and Breustedt and Habermann (2011) found presence of spatial lag dependence; respectively for Irish land prices and German rental rates. The following re-specification corrects for spatial lag dependence:

$$P = \rho WP + \alpha + \sigma R + \gamma I + \delta G + \beta T + \varepsilon, \quad (2)$$

where the spatial lag is composed of an $n \times n$ matrix of spatial weights W with parameter ρ representing the spatial structure among all transactions. The element ρW is then multiplied by the dependent variable P (Patton and McErlean, 2003).

Spatial error dependence may be present when spatial effects on land prices are due to unobserved variables that are spatially correlated. For example, information on the depth of the groundwater level is not available. The groundwater level is spatially correlated and affects the yield. Depending on the sign of the correlation, the estimated variances may be either too small or too large (Hardie *et al.*, 2001). In case of spatial error dependence, omitted variables that are spatially correlated with independent variables result in inefficient

estimators compared with OLS (Anselin, 1988). The following re-specification corrects for spatial error dependence:

$$P = \alpha + \sigma\mathbf{R} + \gamma\mathbf{I} + \delta\mathbf{G} + \beta\mathbf{T} + \varepsilon, \quad \text{with } \varepsilon = \lambda W\varepsilon + \xi \quad (3)$$

where $\lambda W\varepsilon$ is a weighted average of the error term at other locations, λ is the coefficient of the spatial autoregressive error term and ξ is a normally distributed error term (IID) (Patton and McErlean, 2003).

Part of the spatial dependence that persists in our data is captured by the explanatory variables. Provinces may serve as a proxy for spatial policies, and population density serves as a proxy for the proximity to residential errors. The size and location of locally fragmented land markets with the related number of buyers and sellers of agricultural land in a certain area can however not be captured by one of the explanatory variables. In order to reflect this, we define the spatial weight matrix for both models and time periods in such a way that each transaction has at least one other transaction connected to it. The spatial weight matrix is then defined based on this radius.

4.5 Results

In this section, we explain the price of agricultural land via the four defined categories: (1) the revenue obtained directly from farming, (2) institutional and transaction regulations, (3) the spatial environment in which the farmer interacts on the land market, and (4) the local market conditions that determine the option value of the land. We split our model into two time periods, one from 2004-2007 and one from 2008-2011. We test whether these two periods are significantly different from each other in two ways; first by testing for the importance of years using an F-test on the full model with and without year-dummies. Second, using a Chow test to compare the two time periods. Both tests are significantly different from zero at the 1% level. This implies that time matters in explaining farmland prices and that the two time

periods are significantly different from each other. We will first explain our choice for the spatial model specification before turning to the model results.

4.5.1 Selection of spatial model

In order to estimate the influence of spatial lag and spatial error dependence, we first specify the spatial weight matrix W . The weight matrix is based on a critical distance band, specified in kilometres. There are three common options to ensure continuity between the different locations: (1) farmers are potentially willing to buy land if they are not separated by a common border, (2) farmers are potentially willing to buy land if they are part of the k nearest neighbours; e.g. only the 10 closest transactions are considered if k is set at 10 and (3) farmers are potentially willing to buy land if they are not further apart from each other than a certain distance. We assume that it is only reasonable for a farmer to buy additional land for farming purposes if the land is located sufficiently close to his current farming operations. We therefore specify a spatial weight matrix based on the third option. For each of the two time periods, we estimate the distance to the nearest transaction and based on that distance construct W . At a distance of 5778, and 6913 meters between the X and Y coordinates of the different transactions for respectively the first and second period, all farms are connected to at least one other farm. We therefore specify the W matrix based on 6000 for period 1 and 7000 for period 2.

In order to test whether spatial dependency is present, we first use a Moran's I test. For both periods, the Moran's I is highly significant at the 1 percent level. As explained in the empirical model, both spatial lag dependence and spatial error dependence may be present. To distinguish between the two we carry out a Lagrange Multiplier test. For both periods, both spatial lag and spatial error dependence are significant, necessitating the need of a robust form specification. Upon considering the robust form for period 1, the error model is only marginally significant, leading us to choose the lag model for period 1 ($LMLag(157.68) < 0.0001$,

LMerr(4.76)<0.05). For period 2, both the Lagrange Multiplier for spatial lag and spatial error dependence remain significant when considering the robust form specification (RLMerr(53.06)<0.0001) (RLMlag(188.94)<0.0001). However, the consistently larger value of the lag model led us to choose the spatial lag model for period 2. The spatial lag model tests whether the price of farmland in one geographical region is directly influenced by the values of farmland found in by other transactions in the same region, above and beyond the explanatory variables already captured in the regression. We consider the spatial lag to be part of the third category, and will therefore discuss this at section 4.5.3. The results of the spatial lag specification compared with OLS results can be found in Table 4.2.

4.5.2 *First category: Revenue obtained directly from farming*

The expected revenue of agricultural land has a positive and significant effect for both time periods. This is as expected because a larger expected net revenue is likely to affect land prices positively. Various studies have showed a capitalization effect of direct payments in the price of land (Weersink *et al.*, 1999; Ciaian and Kancs, 2012; Latruffe and Le Mouel, 2009). The negative and significant sign that we find for the amount of direct payments in the first period and the insignificant sign in the second period may therefore seem contrary to the expectation. However, Ciaian *et al.* (2012) found that only 19 cents of every Euro are captured in land rents and Devadoss and Manchu (2007) also find an insignificant effect of government payments. The effect of government payments is likely to be larger under rental prices than under farmland prices. A further possible reason for the negative effect is that there is less need to buy land if a farm receives a large amount of payments. Moreover, the direct payments are the average direct payments of the buying farm and may therefore relate to the present level of payments of the farmer and not to the additional payments he would receive upon acquiring the additional land.

Farm types characterised by the share of land for arable and grassland use both show significant and negative effects on farmland price. Farm types not considered are e.g. horticultural farms. These other type of farms use relatively less land and are therefore likely to be able to pay more for their land. Although these farms have a higher degree of substitutability it does not lead to a reduction of the price the farmer is willing to pay for additional land, as suggested by Latruffe and Le Moel (2009).

Animal density is measured by the number of cattle, pigs and the LSU per hectare of farmland. Previous studies have highlighted the importance of livestock density to the local competition for land. Breustedt and Habermann (2011) find a significant and positive effect of animal density at the regional level, but not at the farm level. Vulkina and Wossink (2000) further showed that quota policies led to an increase in the price of land for regions where quotas are binding compared with regions where quotas are not binding. This is in line with the results that we find for LSU per hectare of land. The LSU per hectare shows a negative and significant effect for the first period and a positive and significant effect for the second period. Our second time period starts with the announced extension of milk quotas, which are eventually abolished in 2015. The LSU per hectare of land therefore starts influencing the price of land positively when farmers can increase production without buying quota rights. This because in order to expand farm operations, they still need to buy land in order to meet nitrate requirements (Boere *et al.*, 2015).

The size of the farm shows an insignificant effect for the first period and a significant and positive effect for the second period. The effect for the second period implies that the larger the farm is in terms of hectares, the higher the price it is willing to pay for the land. This could represent economies of scale; larger farms are able to obtain a larger net revenue per hectare of agricultural land. Farm size may capture productivity differences; larger farms are able to offer a higher price for land compared with the average NPV. The previous literature is not

conclusive on the relationship between farm size and productivity, Ciaian and Kancs (2012) for example find very small negative effects.

The age of the farmer is only significant for the first period, showing a negative effect for age and a positive effect for age squared, and implying life cycle patterns in farmland transactions. Life cycle patterns imply that the advantage of increasing farming operations is increasing up to a certain age, after which it is decreasing (Gale, 2003). They may reflect different things, such as bargaining power, opportunity costs and the farmer's lifetime working cycle (Breustedt and Habermann, 2011). Breustedt and Habermann (2011) find an insignificant effect for age, but this may be because they did not include age squared.

For none of the periods the quantity of labour shows a significant effect on the price of land. However, the productivity (quantity of labour per hectare) is highly significant for both periods. This, together with the positive effect for farm size observed in the second period captures the efficiency of farms; showing that more productive farms are able to offer a higher price for land.

4.5.3 *Second category: Institutional and transaction regulations*

Transaction regulations, and especially institutional regulations, are of large importance in explaining farmland prices (Ferguson, 2005). Ownership may be permitted to only certain types of buyers, or regulations regarding the size and price of the transaction may be imposed by governments (Ay and Latruffe, 2013). If the land is fully or family owned, this has a large positive impact on the price of land. With full or family ownership the investment is more secured compared with for example ownership with leasehold. Further institutional and transaction regulations are represented by whether the seller is a private person. In that case, positive and significant effects are found for both time periods; implying that private persons can pay a higher price for the land than e.g. governmental bodies. It may also be the case that transaction costs, such as search and monitoring costs, are higher if two private persons have

to meet than when the seller of land is e.g. a government body or a bank, who typically have more information available. Government bodies or banks often have more information on land prices and supply and demand in the market and may buy land with the idea of future development into for example residential areas. They also have to bear less costs, such as registration costs, and notary fees (Ay and Latruffe, 2013). The number of hectares involved in the transaction does not seem to have an influence on the price of farmland. This is counter-intuitive because transaction costs per hectare of land are likely to decrease with the size of the transaction. It may be that this effect is already captured by the aforementioned variables.

4.5.4 *Third category: Spatial environment in which the farmer interacts in the market*

The large significance of the coefficients for the individual provinces show that the geographical region matters in explaining the price of land. We find both positive and negative coefficients, which is in line with the existing literature that suggests that land-use regulations may have different effects (Jaeger *et al.*, 2012). The large significance of the coefficients is mostly due to land-use regulations that are set on a provincial level. They include for example zoning policies that limit urban sprawl (Ay and Latruffe, 2013). In the first period, the price of land has a positive and significant effect (compared with the province Limburg in the South of the Netherlands) in the more urbanized provinces Utrecht, Noord-Holland and Zuid-Holland and a negative and significant effects for the rural provinces Groningen, Friesland and Drenthe. Near cities agricultural land faces pressure from other uses such as housing and infrastructure which commonly entail larger land prices. In more urban regions this may therefore lead to spill-over effects in the price of land. This is largely similar for the second period, except that the province of Noord-Holland is not significant anymore. This may have to do with the fact that after the financial crisis, the urban influences of this province have become less important.

Land-use regulations often have an environmental goal also, for example by preserving environmental benefits and storage for ground water (Ay and Latruffe, 2013). In the Netherlands, the nitrate regulation is a good example of such regulation. This especially applies for areas with a high density of livestock, which occurs mostly in the provinces Drenthe, Overijssel, Utrecht, Noord-Brabant and Limburg. Indeed, the province Overijssel was insignificant in the first period, but significant in the second period, capturing the start of the quota enlargement.

The Lagrange Multiplier test showed that spatial lag dependence is present in our data. Hence, the price of farmland in the local spatial environment is directly influenced by the values of farmland found in the same environment, above and beyond the explanatory variables already captured in the regression. This implies that the price of a parcel affects the price of the parcels in the vicinity directly. Property owners, prospective buyers, real estate agencies, tax assessors and others base their estimates of values of agricultural land on observed sales in the vicinity (Patton and McErlean, 2003). If there is a larger number of actors interacting in the vicinity of the transaction, this is likely to result in a larger price offered for the land.

4.5.5 Fourth category: Local market conditions that determine the option value of land

The dummies for each quarter of the year show that there are seasonal fluctuations present in the data. Over both periods, the second half of the year results in higher land prices compared with the first half of the year. This may be for agronomic reasons; in order to profit from the newly acquired land, a producer needs to buy land before the new planting season starts.

Especially in the second period, the year-dummies show significant results, indicating that land prices rise faster in certain years than in others. This may be caused by speculative effects on future returns and future use of the land. This is in line with Power and Turvey (2010) who suggest that the volatility of rural land values exists mostly in the short term and thereby find

evidence for a short-run bubble in farmland prices in the US. This may also explain the difference compared with Tegene and Kuchler (1993) who did not find evidence for a rural land market bubble, but instead focused on the long term. In the first period, we only find a significant and positive effect for the year 2004. In the second period, significant and positive effects are found for all years. This implies a negative effect for 2008, the year of the onset of the financial crisis. In line with Power and Turvey (2010) we do however also use a short time horizon.

In both periods, population density shows a significant and positive result, implying an option value of land in anticipation of the transformation of agricultural land into for instance residential land. Moreover, a higher nearby population density may increase the demand for agricultural products and may lead to larger positive externalities of farmland near residential areas (e.g. the valuation of farmland), also leading to larger farmland prices (Devadoss and Manchu, 2007)

Table 4.2: Regression results

Variable	Period 1 OLS		Period 1 Lag		Period 2 OLS		Period 2 Lag	
	coeff	sign	coeff	sign	coeff	sign	coeff	sign
Revenue obtained from farming								
Expected net revenue	0.00	***	0.01	**	0.03	***	0.02	***
Direct payments	-0.01	**	-0.01	***	0.00		0.00	
Share of arable land	-0.89	***	-0.53	***	-1.15	***	-0.84	***
Share of grassland	-1.04	***	-0.64	***	-1.56	**	-1.07	***
Cattle	0.00		0.00		0.00		0.00	
Pigs	0.00		0.00		0.00		0.00	
LSU/ha	-0.02	***	-0.02	***	0.02	*	0.01	*
Size	0.00	***	0.00		0.00	**	0.00	***
Age	-0.02	*	-0.02	**	-0.02		-0.01	
Age squared	0.00	**	0.00	**	0.00		0.00	
Labour	0.00		0.00		0.00		0.01	
Productivity	0.36	***	0.30	***	0.30	**	0.30	***
Institutional and transaction regulations								

Private seller	0.64	***	0.60	***	0.63	***	0.60	***
Full ownership	0.64	***	0.66	***	1.25	***	1.20	***
Ha transacted	0.00		0.00		0.00		0.00	
Spatial environment ^{a)}								
Groningen	-0.39	***	-0.16		-0.59	***	-0.20	**
Friesland	-0.59	***	-0.28	***	-0.44	***	-0.05	
Drenthe	-0.89	***	-0.45	***	-0.92	***	-0.33	***
Overijssel	-0.06		0.00		0.53	***	0.30	***
Flevoland	0.44	***	0.52	***	1.68	***	0.88	***
Gelderland	0.18	**	0.09		0.42	***	0.26	***
Utrecht	0.91	***	0.52	***	0.70	***	0.41	***
Limburg								
Noord-Holland	0.51	***	0.23	**	0.12		0.06	
Zuid-Holland	0.78	***	0.45	***	0.67	***	0.39	***
Zeeland	-0.08		-0.05		0.05		0.18	**
Noord-Brabant	0.66	***	0.33	***	1.07	***	0.48	***
Local market conditions ^{a)}								
Q2	0.04		0.03	*	0.06		0.07	
Q3	0.35	***	0.32	***	0.31	***	0.25	***
Q4	0.17	***	0.15	***	0.31	***	0.28	***
2004	0.22	***	0.20	***				
2005	0.09	*	0.08					
2007	0.05		0.05					
2009					0.84	***	0.81	***
2010					0.35	**		
2011					0.27	***		
Population density	0.05	***	0.03	***	0.06	***	0.04	***
Constant	2.63	***	0.53	***	3.44	***	0.61	*
Rho			0.46	***			0.58	***

^{a)}Province Limburg, Q1 and 2006 and 2008 for respectively period 1 and 2 treated as base category.

4.6 Discussion and Conclusions

In 2008 an economic crisis hit the Netherlands, like the rest of the world. This gives a unique opportunity to analyse the effect of the economic crisis on farmland prices. The objective of this paper is to explain farmland prices in the Netherlands and to analyse the effect of the

financial crisis on the land market price, controlling for other factors explaining farm land prices. In order to do so, we defined four categories explaining farmland prices: (i) The revenue obtained from farming the land. (ii) Institutional and transaction regulations. (iii) The spatial environment in which the farmer interacts on the land market. (iv) Local market conditions that determine the option value of land. In order to account for the influence of the financial crisis, we divide the Netherlands in two time periods; one from 2004 until 2007; and one from 2008 until 2011. Moreover, we have corrected for spatial influences by testing for spatial lag and spatial error dependence. We found evidence of spatial lag dependence, implying that the price of farmland in the local spatial environment is directly influenced by the values of farmland found in the same environment, above and beyond the explanatory variables already captured in the regression.

All of our four categories show significant coefficients and are thereby important in explaining farmland prices. With respect to the first category, larger expected net revenue, more intensive farm types compared with grassland or arable land and more efficient farms will induce a higher price of farmland. With respect to the second category, full or family ownership and a private seller induce a higher price of farmland. With respect to the third category, zoning policies likely lead to higher land prices nearby cities and agricultural policies lead to higher land prices in provinces with a manure surplus. Moreover, the announcement of milk quota abolition in 2008 has led to higher land prices. With respect to the fourth category, seasonal fluctuations relating to planting times and volatility in years exist and population density has a positive effect on farmland price.

The difference in results between the two periods are generally small; except for LSU per hectare, no differences in both sign and significance are observed between the two periods. However, certain variables have become (more) significant or have resulted in a larger impact. With regard to the first category, the negative impact of the share of grassland and arable land of the farm on the land price has become more pronounced. Moreover, the size of the farm

has become positive and significant and the number of LSU per hectare of land has changed from negative and significant to positive and significant. The larger effect of share of grassland and arable land and size of the farm may imply that farm-specific factors making the farm-specific revenue deviate from the average revenue have become more important. The positive and significant effect of LSU per hectare together with the positive and significant effect of Overijssel may indicate that land use regulations, and more specifically the nitrate regulation have become more important in the second period.

Changes are observed to the spatial environment in which the farmer interacts on the market as well. Noord-Holland, the most urban province of the Netherlands, does not show a significant effect (compared to Limburg) on the price of land anymore. Furthermore, the significant and positive effects found for all years in the second period imply a smaller effect for 2008. Together, this provides limited indication that the onset of the financial crisis had a negative effect on farm land prices. The announcement of the milk quotas however had a positive effect on farm land prices. So, the spatial environment in which the farmer interacts, as well as the local market conditions that determine the option value of land have changed in importance.

To our understanding, this paper provides a first comprehensive analysis general and local economic factors influencing the price of farmland, accounting for both space and time, at the farm level. However, there are also caveats to this study, the most important being that we were not able to determine the farm-specific NPV. We have tried to overcome this by including the farm-type specific expected net revenue and by capturing differences between the farm-specific net revenue and the average net revenue using farm-specific variables such as age and labour productivity.

CHAPTER 5. TOWARDS THE GREENING OF AGRICULTURAL PAYMENTS: THE EFFECT OF RECENT CAP REFORM ON CROPPING DECISIONS¹

Abstract

This chapter analyses the potential impact on producers' land-use decisions in moving from support payments based on entitlements to a single farm payment (SFP) and then to a single farm payment with a greening component as part of the 2013 CAP reform. Using data for representative Dutch arable farms of different sizes, we develop a farm-level crop allocation model that is calibrated using positive mathematical programming. We use a two-step calibration method to determine a nonlinear cost function and farm-specific risk aversion coefficients. We find that the 2013 CAP reforms will cause farmers to shift away from crops previously eligible for payments, with the initial shift under the SFP enhanced by the move towards SFP combined with green payment.

¹ Paper by Esther Boere and G. Cornelis van Kooten. *Submitted to a peer-reviewed journal.*

5.1 Introduction

Europe's Common Agricultural Policy (CAP) has increasingly focused on liberalizing markets by decoupling payments from production, and linking them to the provision of environmental services. The 1992 MacSharry reform laid the foundation for the transition from market protection and price support policies to a direct income payment system. Products receiving price support, such as cereals, oilseeds, tobacco, milk, beef and lamb, saw a reduction in levels of protection, with producers receiving direct payments in return. This transition was reinforced by the reforms that followed: Agenda 2000, the 2003 Mid-Term Review (Fischler reform), the 2008 Health Check, and, more recently, the 2013 CAP reform. Direct payments can therefore be seen as the embodiment of the move away from support measures for specific products towards less market-distorting agricultural support where subsidies are paid directly to farmers, conditional upon certain practices but decoupled from production. An important step in this direction was the 2003 Mid-Term Review that gradually introduced the Single Payment Scheme (SPS) between January 2005 and January 2007. Direct payments were decoupled from production but linked to eligible farmland, although coupling elements were retained in some programs, notably dairy, cereals, sugar beets and starch potatoes.

Under the 2003 reforms, countries could choose (1) an approach where entitlements depended on farm-specific historical reference amounts, (2) an approach where entitlements depended on the region's outcomes for establishing a reference margin, or (3) a hybrid of the historic and regional approaches (European Commission, 2014a). While the European Commission expressed a preference for the regional model, the majority of countries opted for the historical one (Matthews *et al.*, 2013). Under the historic approach, only lands growing specific crops were considered eligible for fixed payments (€/ha) that varied by crop based on historic 2000-2002 yields; additionally, payments depended on cross-compliance measures linked to environmental standards (Helming *et al.*, 2010). Because payments were based on farm-

specific entitlements, their size differed significantly by type of farm and across farms (Helming and Peerlings, 2014).

When subsidies are completely decoupled from production, one would expect the levels of output with and without subsidies to be equal (Hennessy, 1998). However, production decisions may be affected indirectly because flat-rate payments based on historic reference amounts result in an *insurance effect*, because it provides an effective lower bound on a producer's income, and a *wealth effect*, because it increases a farmer's wealth and thereby reduces his level of risk aversion (Finger and Lehmann, 2012; Hennessy, 1998). Decoupled payments do not affect price variability and thus are not expected to have an insurance effect. Wealth effects, on the other hand, are likely to be small and producer specific, although some evidence suggests the wealth effect could still have a slight impact on crop choices (Sckokai and Moro, 2009; Koundouri *et al.*, 2009). Wealth effects only occur under the assumption of decreasing absolute risk aversion, where the farmer becomes less risk-averse with an increasing expected payoff. Since the payoff would need to be quite large to have a significant impact on wealth in any one year, we assume that a farmer's risk-aversion is unaffected by the expected change in wealth as a result of his crop allocation choices.

Besides potential insurance and wealth effects, there is an extensive literature evaluating the other effects that the decoupled payments of the 2003 Mid-Term Review had on farmers' decisions (for a review see Bhaskar and Beghin, 2009). These include impacts on investment decisions caused by increased access to credit (Sckokai and Moro, 2009), changes in on- and off-farm labour allocations (Key and Roberts, 2009; Hennessy and Thorne, 2005), changes to inputs or other activities that would increase output (Hauser *et al.*, 2004), increased land and rental prices (Brady *et al.*, 2009), and, related to prices, competition for land between agricultural markets (Gohin, 2006). On a broader scale, direct payments impacted land abandonment and biodiversity (Brady *et al.*, 2009; Mosnier *et al.*, 2009; Bhaskar and Beghin, 2009; Key and Roberts, 2009), affected prices/markets (Balkhausen *et al.*, 2008; Gohin, 2006),

and led to the distortion of subsidies on production (Dewbre *et al.*, 2001; Burfisher and Hopkins, 2003). Except for the effect of decoupled payments on land prices, the impacts of all these effects tend to be rather small (Hennessy and Thorne, 2005; Sckokai and Moro, 2009; Koundouri *et al.*, 2009; Key and Roberts, 2009), certainly in comparison to other support mechanisms (Dewbre *et al.*, 2001; Burfisher and Hopkins, 2003). However, most changes were analysed at the national or large-region scale and not at the farm level, leading to general instead of farm-specific statements about land-use change.

The CAP reform of 2013 introduced a single farm payment (SFP) that would eventually provide the same level of support to every hectare of agricultural land within a region, independent of the type of farm or crop grown – it is a flat rate payment. In addition, producers can be compensated for providing public goods in the form of environmentally-friendly farming practices – a so-called greening component that is added to the new SFP (SFP&GP) if farmers are in compliance (European Commission, 2014a). The most important restriction imposed by the greening component is a set-aside requirement referred to as the Ecological Focus Area (EFA). Estimates for the Netherlands indicate that some 12,500 farms with a total area of 670,000 hectares have to apply EFA measures to meet the greening criteria, implying 33,500 hectares of EFA (Bron *et al.*, 2014).

The objective of this chapter is to analyse the farm-specific effect that the different payment mechanisms, including the single farm payment and green payment (GP), have on land use (crop allocation) decisions. In essence, we compare the direct payment reforms on cropping decisions using the Netherlands as a case study. For the Netherlands, it is expected that the SFP will lead to a lower level of income support and an increase in income uncertainty (Helming and Peerlings, 2014). Thus, we investigate if, and under what circumstances, this implies enhanced greening practices for farms of different sizes.

We begin our analysis in the next section with a description of our crop allocation model, which employs representative farms of various sizes, followed in section 5.3 by a summary of

the Dutch data employed in this application and how the data are used to calibrate our model using PMP. Our simulation results comparing historic, SFP and SFP&GP follow in section 5.4. Our conclusions ensue.

5.2 Farm-level crop allocation models

In deciding how to allocate his land among different uses, the agricultural producer takes into account government support payments. Three stages in the reform of direct payments for the Netherlands are indicated in Table 5.1. Before 2006, payments were linked to crops, leading to payments up to €9,560 for an average arable farm. Then the Mid-Term Review led to a significant but not total shift to decoupled direct payments starting in 2006. Finally, beginning 2015 direct payments were fully decoupled and are now linked to greening criteria. Our purpose is to determine the potential effect that these three stages have on the way the farmer allocates his land to various crop activities. We do this using a farm-level crop allocation model for representative Dutch arable farms of different sizes.

We assume that the producer selects the crops to plant in a way that addresses two conflicting objectives: the farmer seeks to maximize expected net returns from his land-use decision while minimizing the variance of returns. For example, the objective might be to maximize expected utility using a mean-variance approach where the expected net return is adjusted for risk. In that case, risk is defined as the variance in net returns associated with the crop portfolio multiplied by the Arrow-Pratt absolute risk aversion coefficient (discussed below). Further, we calibrate the model using positive mathematical programming (PMP) (Howitt, 1995).

We begin by constructing a base farm-level crop allocation model that includes a direct payment (€/ha) based on historic entitlements that are assumed to be in place until 2012 (first stage). Then we discuss how we calibrate our crop allocation model using PMP. Finally, we describe how the model needs to be modified to take into account flat-rate direct payments (second stage) and, subsequently, direct payments that include an option for higher payments

by meeting certain greening requirements (third stage). In Table 5.1, these are referred to as CP, SPS and SFP, respectively.

Table 5.1: Amount and type of payments for an average arable farm in the Netherlands

Type of support	Year	Coupled payments (€)	Direct payments (€)	Size of average arable farm (ha)
CP	2001	5,340		50.7
CP	2002	7,180		51.1
CP	2003	7,900		52.7
CP	2004	9,560		53.2
CP	2005	9,310		55.1
SPS	2006	2,390	17,390	55.2
SPS	2007	2,750	18,270	57.6
SPS	2008	3,130	20,150	58.7
SPS	2009	2,840	21,880	59.4
SPS	2010	2,940	23,090	59.1
SPS	2011	3,170	24,750	59.4
SPS	2012		29,210	59.5
SFP	2013			

Source: LEI (2014e)

5.2.1 Base Model and Flat-Rate Payments

For the average arable farm in the Netherlands, the crops previously eligible to receive payments were wheat, barley and sugar beets. A farmer received the subsidy as long as his eligible land is planted to one of the eligible crops, independent of the precise distribution of crops within the eligible set (RVO, 2015). In our model and based on payments as of 2006, we employ the fixed crop-specific direct payments provided in Table 5.2. Sugar beets are still coupled and subject to a quota regime. Therefore, only wheat and barley can be freely allocated within the eligible hectares to receive payments. For reasons of simplicity, we model the payments in Table 5.2 as if they were crop-specific.

Table 5.2: Fixed crop-specific payment based on historic 2000-2002 yields

Crop	Payment (€/ha)
Wheat	377.5
Barley	377.5
potato	0
sugar beet	687.0
Onions	0

Source: Hermans *et al.* (2006)

Expected income and its variance are affected by the subsidies agricultural producers receive. We assume that farmers maximize their gross margins (defined as the difference between crop revenue and identifiable variable costs), while accounting for risk in their production decisions; thus, in the current context, an arable farmer with a fixed amount of land and facing exogenous input and output prices seeks to maximize his expected utility by allocating land to various uses. Expected utility is determined by the expected overall gross margin, the variance-covariance matrix of gross margins, and the Arrow-Pratt measure of absolute risk aversion (denoted ϕ). The allocation problem can be specified as:

$$\text{Maximize } U = \sum_{k=1}^K E[R_k] - \frac{1}{2} \phi \sigma^2 \tag{1}$$

Subject to:

$$R_{k,t} = [p_{k,t} y_{k,t} - c_k(w) + SPS_k] x_k, \forall k \tag{2}$$

$$\sigma^2 = \sum_{k=1}^K \sum_{i=1}^K [x_k \times CV(R_k, R_i) \times x_i] \tag{3}$$

$$CV(R_k, R_i) = \frac{1}{T} \sum_{t=1}^T (R_{k,t} - E[R_k])(R_{i,t} - E[R_i]), \forall k, i \tag{4}$$

$$E[R_k] = \frac{1}{T} \sum_{t=1}^T R_{k,t}, \forall k \tag{5}$$

$$\sum_{k=1}^K x_k \leq \bar{X} \quad (6)$$

where U refers to the representative farmer's utility; $\sum E[R_k]$ is the expected total gross margin from crop production; $\phi = -U''(w)/U'(w)$, where $U(w)$ is specified as an exponential utility function of wealth w ; σ^2 is the risk associated with the total crop portfolio; $p_{k,t}$ and $y_{k,t}$ represent, respectively, the output price and yield for crop k in period t ; SPS_k is the historic reference payment (€/ha) for crop k ; and $c_k(w)$ is the per unit-area variable cost of producing crop k as a function of exogenously-determined input prices w . $CV(R_i, R_k)$ refers to the covariance matrix, where R_i and R_k refer to the respective realized gross margins to crops i and k , and $E[R_k]$ is the farmer's expected overall gross margin (€/ha) from planting crop k ; there are K crops that can be planted in any period; x_k denotes the number of hectares allocated to produce crop k ; and \bar{X} represents the total area (ha) the farmer allocates to crop production. Finally, T refers to the number of past years used to generate the expected gross margins and the variance-covariance matrix.

Equations (2) through (5) are accounting identities. Equation (2) calculates the gross margin accruing to each crop in each period given the allocation of land to crops, which is endogenously chosen in the model. SPS_k is included in (2) because we model payments based on entitlements as payments varying by crop. Equation (3) specifies the risk associated with the total crop portfolio, while equation (4) provides the variance-covariance matrix. Based on historic data, equation (5) calculates the expected (mean) revenue that accrues to each crop and is used in each of our model simulations. An additional constraint (6) restricts the farmer's

² This implies constant absolute risk aversion (CARA) as discussed below. Notice that some authors specify utility as a function of consumption or income rather than wealth, but this can be confusing in the current context as explained in the next section (compare Freund, 1956; McCarl and Bessler, 1989; Petsakos and Rozakis, 2011).

cultivated area to that which is available. In each period, the producer must decide how to allocate his \bar{X} hectares among the K different crops so as to maximize utility.

5.2.2 Model Calibration

The PMP procedure for calibrating a model in which the objective is simply to maximize the gross margin from allocating a fixed amount of cropland to a variety of crops is now well known (Howitt 1995, 2005). The calibration procedure is first to maximize $E[R]$, as given in equation (5), where R_k is a linear function, subject to (2), (3), (4) and (6) plus added calibration constraints (discussed below). Notice that, at this stage, linearity implies that $c_k(w)=c_k$, where c_k is the (fixed) average cost of producing crop k (€/ha); it is this average cost that is the only cost component commonly available to the researcher.

Using the 1st-stage PMP results, the linear objective function is then adjusted to include nonlinear terms (Heckeley *et al.*, 2012). Nonlinearities might arise, for example, as a result of unobserved differences in soil quality, topography or to account for other physical attributes of the land such as crop rotation, as well as anticipated government programs, labour availability, et cetera. These unobserved attributes result in increasing marginal costs as more of a particular crop is planted on a farm (Howitt, 1995). Upon taking these factors into account, a smooth supply response can be detected, and continuous changes in land use responses can be identified by changing the (exogenous) policy variables, avoiding over-specialisation and unrealistic responses in land uses (Röhm and Dabbert, 2003).

The PMP method is somewhat more complicated when the objective is to maximize expected utility rather than the total expected gross margin. In that case, one should also calibrate the absolute risk aversion parameter. Petsakos and Rozakis (2011, 2015) provide a more complete model in which observed plantings and a covariance matrix of gross margins are needed to calibrate the crop-allocation model. Rather than assuming an exponential utility function which leads to a constant absolute risk aversion (CARA) parameter, Petsakos and Rozakis

(2015) assume a logarithmic function and thus a decreasing absolute risk aversion (DARA) coefficient that is a concave function of wealth. Specification of an initial level of wealth is required so that DARA changes in response to the farmer's cropping choices. In their application, the authors choose an initial level of wealth given by the single farm payment. However, this is more suited to the situation where the level of initial wealth is larger than that given by SFP, primarily because a producer's total wealth is not likely to change dramatically from one crop year to the next, making a normal wealth distribution more likely; if wealth is set equal to SFP, small changes in annual returns will have too great an impact on wealth. Producers face different kinds of uncertainty and increased output price volatility caused by the EU's shift towards SFP does not necessarily imply changes in the level and variance of income (Pennings *et al.*, 2010; Moschini and Hennessy, 2001). Perceived risk may therefore depend more on the person rather than changes in wealth. As a result, and to allow comparison of the degree of risk aversion among farmers, we characterize the farmer's risk aversion by CARA rather than DARA. In this chapter, we assume different farmers with varying degrees of risk aversion. In order to do so, an exponential utility function and normal distribution of wealth are required.

A method for specifying the CARA parameter ϕ is nonetheless still required. In the current application, we vary ϕ for the small, medium and large representative producers in an iterative fashion in order to come close to duplicating the observed crop allocation (see Jeder *et al.*, 2011).³ We begin with the standard PMP approach identified in Howitt (2005) that starts by introducing the following calibration constraints:

$$x_k \leq x_k^0 + \varepsilon_k, \forall k, \quad (7)$$

where the superscript denotes observed land use and ε_k are small perturbations required to avoid degeneracy of the shadow prices. The calibration constraints put an upper limit on

³ This is discussed in more detail in section 3.3 below.

simulated land-use allocations. Since it is not possible to infer the crop specific costs as functions of input prices, cost functions $c_k(w)$ are replaced by observed average variable costs in (2). More specifically, we assume that $c_k(w)=c_k(x_k)=c_k^0$ (€/ha), or a farm-specific value set to the observed average cost of producing crop k . Thus, the cost of planting, tending and harvesting crop k is now assumed to be a function of how much land is allocated to that crop. In the second step, the dual values associated with the calibration constraints are used to parameterize a nonlinear cost or production function; in this case a quadratic cost function is specified. The revenue function (2) becomes a function of land use as follows:⁴

$$R_k(x_k) = p_k y_k - c(x_k) = p_k y_k - (\alpha_k x_k + \frac{1}{2} \beta_k x_k^2) + SPS_k x_k, \quad (8)$$

with $c(x_k) = \alpha_k x_k + \frac{1}{2} \beta_k x_k^2$ an assumed quadratic cost function. Now, for each crop, the shadow price λ_k is simply the difference between the marginal (MC_k) and average (AC_k) costs:

$$\lambda_k = MC_k - AC_k = (\alpha_k + \beta_k x_k) - (\alpha_k + \frac{1}{2} \beta_k x_k) = \frac{1}{2} \beta_k x_k. \quad (9)$$

Given observed values for yields, crop prices, average per ha production costs and the allocation of farmland to various crops, it is possible to derive α_k and β_k from the shadow prices λ_k determined in the first step:

$$\beta_k = 2\lambda_k/x_k^0 \text{ and } \alpha_k = c_k^0 - \lambda_k - SPS_k. \quad (10)$$

In the third step, the calibration constraints are removed; i.e. $c(x_k)=c_k^0$ is replaced by $c(x_k)$, and ϕ is varied until it exactly duplicates observed land allocation. Given the parameterized objective function and the farm-specific value for ϕ , it is now possible to simulate changes to the policy variables. The revised revenue equation used in place of equation (2) is:

⁴ The subscript t has been dropped as we calibrate the model to land uses observed in our base year.

$$\sum_{k=1}^K R_k = \sum_{k=1}^K [p_k y_k - (\alpha_k + 0.5\beta_k x_k) + SPS_k] x_k . \quad (11)$$

5.3 Description of the Model Farms

In this section, we first examine the data and then present the results of the PMP analysis using a trade-off function that gradually increases the risk-aversion coefficient for the representative crop farms of different sizes under payments based on entitlements.

5.3.1 Data and Descriptive Statistics

Our study focuses on representative arable farms of different sizes in the Netherlands that have a mixed crop portfolio. We use the Farm Accountancy Data Network (FADN) to select representative small, medium and large farm sizes. For each of our representative farms, farm specific land allocations, prices, yields and costs are reported in Table 5.3. Because the FADN employs a representative sample of farms, it was not possible to gather historic data per representative farm. Thus, we took a sample of farms within the farm size classes to establish historic prices, yields and costs for the three representative farms.

Farm specific data from the FADN (LEI, 2014e) for the period 2000 through 2012 were used to measure annual variations in prices, yields and costs. Variable costs were calculated by crop per hectare and include costs of seed, pesticide, fertilizer, energy and other costs for crop activities. Given available yield and price data, net revenues were calculated for all cropping activities. A summary of net revenues and their variances for 2012 is also found in Table 5.3. By employing information from the PMP calibration, we establish farm plans for each of the representative farms to use for simulating different scenarios for direct payments as part of the CAP reform.

Table 5.3: Land allocations, yields, prices, costs and revenues and their variance for the small, medium and large farm.

Crop	Observed ha	Yield (100 kg/ha)	Price (€/100 kg)	Variable cost (€/ha)	Gross margin (€/ha) ^a	Variance gross margin (€/ha)
SMALL						
wheat	10.45	78.4	22.91	911.59	884	390,468
barley	5.06	63.08	22.54	564.34	858	125,037
potato	10.55	387.09	17.29	2,174.90	4,519	1,561,499
sugar	8.15	773.61	6.07	1,160.29	3,539	354,382
Onion	5.72	748.5	11.51	2,388.67	6,223	7,926,375
Total	39.93					
MEDIUM						
Wheat	19.31	86.1	24.23	647.25	1,439	131,076
Barley	10.8	75.45	23.62	489.11	1,293	107,267
Potato	12.68	424.94	18.87	2,357.02	5,660	2,255,007
Sugar	8.83	803.63	6.22	1,080.62	3,920	350,510
Onion	7.79	629.73	11.62	2,184.60	5,131	8,203,962
Total	59.41					
LARGE						
Wheat	35.02	88.6	23.63	593.23	1,500	126,251
Barley	14.97	73.52	24.96	387.34	1,448	109,852
Potato	26.37	455.72	18.94	2,253.42	6,379	1,740,431
Sugar	17.08	794.51	6.39	993.48	4,083	447,065
Onion	13.09	579.3	10.98	2,227.38	4,133	6,841,132
Total	106.53					

Source: Farm Accountancy Data Network (LEI, 2014e)

^a Farmers initially receive payments based on entitlements which have not yet been included.

5.3.2 PMP calibration

To model our various scenarios, we develop a mathematical programming model in GAMS (Rosenthal, 2008). We begin by maximizing the overall gross returns subject to technical and

observed land-use calibration constraints of the representative farms (Table 5.3). The gross margin is calculated for each crop as price \times yield minus variable cost using the data in the table. In Table 5.4 we provide the estimated slope coefficients, but only for four PMP activities as barley continues as a non-marginal (linear) activity for all farm sizes as its calibration constraint was not binding ($\lambda_b=0$).

Table 5.4: Calibrated slope (β) coefficient for the small, medium and large farms

Crop	Small	Medium	Large
Wheat	27.07	145.93	52.67
Barley	0	0	0
Potatoes	3656.63	3991.08	4552.7
Sugar beets	2681.14	2934.44	2945.22
Onions	5365.31	3462.34	2308.11

For barley, outside information is needed to distinguish between average and marginal cost. Following Howitt (2005, pp.88-91), we employ the elasticity of land supply with respect to output price: $\eta_s = (\partial q / \partial p) (p/q) = (\partial x_b / \partial MC_b) (p_b / x_b^o)$, where x_b^o is the observed land in barley and p_b is the output price for barley. Recall from (9) that $MC_k = \alpha_k + \beta_k x_k$, so $\partial MC_b / \partial x_b = \beta_b = p_b / (\eta_s \times x_b^o)$. Now define an adjustment at x_b^o that is added to the LP average cost to obtain a nonlinear cost function: $Adj = MC - AC = \frac{1}{2} \beta_b x_b^o = p_b / 2\eta_s$. If the adjustment applies to the marginal activity – the activity whose calibration constraint is not binding – then the PMP values for the non-marginal activities (whose calibration constraints are binding) must also change as follows:

$$\hat{\lambda}_k = \lambda_k + Adj. \tag{12}$$

The choice of value for the elasticity of land supply for the non-marginal activity differs between studies, even for the same crops (Jongeneel, 2000; Salhofer, 2000; Helming, 2005; Helming and Peerlings, 2014). Following Salhofer (2000), who indicates that elasticities of land supply must be between 0 and 1, and based on a previous study using the same period and study area, we choose $\eta_s = 0.174$ for barley with respect to land (see Chapter 2). The farm-

specific results for $\hat{\lambda}_k$, α_k and β_k that are obtained after re-calibration of the PMP model are presented in Table 5.5.

Table 5.5: Shadow prices and PMP calibrated marginal cost functions for the small, medium and large farm^a

Crop	Small		Medium			Large			β
	λ	α	β	λ	α	β	λ	α	
Wheat	4113	-3201	787	5267	-4620	545	5326	-4733	304
Barley	4086	-3521	1616	5121	-4632	949	5273	-4886	705
Potatoes	7742	-5567	1468	9112	-6755	1437	9826	-7572	745
Sugar beets	6767	-5607	1660	8056	-6975	1824	8218	-7225	962
Onions	9451	-7062	3304	8583	-6399	2203	7581	-5354	1158

^a Recall that $MC_k = \alpha_k + \beta_k x_k$, where λ_k is the shadow price of the calibration equation for crop k determined from GAMS and α_k and β_k are derived using equation (11). In doing so, SPS was added to α_k and then used to calculate β . The shadow price for total land use is the shadow price found for the total land use constraint. Values are in €/ha.

5.3.3 Revenue-variance trade-offs under varying levels of risk-aversion

Next, we construct a frontier based on the model described above where we vary the level of the risk coefficient from very low to very high values, each time finding the related revenue and variance of revenue. The resulting frontiers for the representative small, medium and large farms are shown in Figure 5.1, but with risk measured as standard deviation. If the farmer has a very low risk-aversion coefficient, and focuses primarily on maximizing revenue, he is at the upper right of his frontier. If the farmer places much more emphasis on minimizing risk, he is at the bottom left of his frontier. The total difference in potential revenue between these two points is less than 1%, 9% and 4% for the small, medium and large farms, respectively, indicating that a very small reduction in income leads to a relatively large increase in the risk coefficient. The corresponding optimal planting strategies change gradually as the risk coefficient changes, as indicated in Figure 5.2 below.

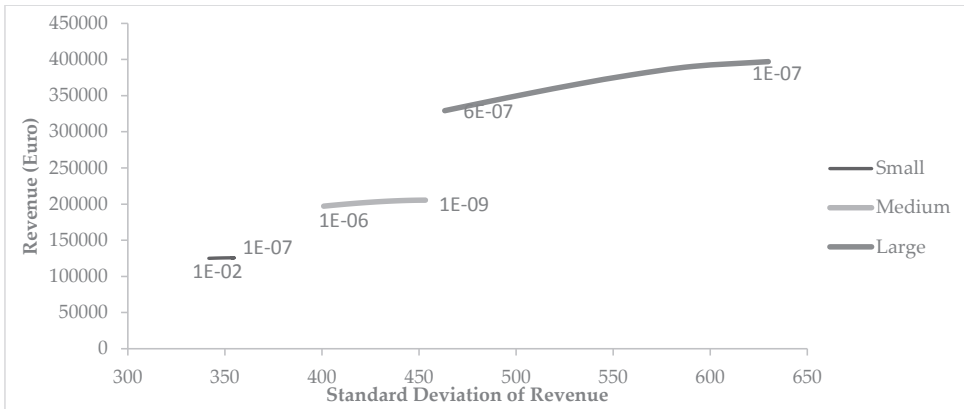


Figure 5.1: Trade-off between revenue and standard deviation at given levels of risk aversion for representative small, medium and large farms.

If we knew a producer's utility function (or aversion to risk), we would be able to identify the optimal allocation of land to various crops. In step 3 of the PMP model, we calibrate the risk coefficient by iteratively increasing the value of ϕ to the point where it begins to impact the calibrated (observed) crop allocation. The objective function in equation (1) then includes calibrated costs in $E[R_i]$ and the maximum possible value for ϕ that still retains the observed land allocation. For small, medium and large farms, we find respective values of 17.5×10^{-6} , 0.012×10^{-6} and 0.001×10^{-6} for the absolute risk aversion coefficient. The risk aversion coefficient of the small farm is much larger than that of the medium and large farms, whereas the risk aversion coefficient differs to a much lesser extent between the medium and the large farm. The differences in coefficients are as expected. The risk aversion coefficient of a small producer is greater than that of a large producer, suggesting that the absolute risk aversion coefficient does indeed decline with increasing wealth.⁵ In their seminal paper, McCarl and Bessler (1989)

⁵ Because our 'calculation' of the risk coefficient follows the PMP calibration, the actual value of farmers' risk aversion coefficients is likely different from that estimated here because the calibration method may account for some risk considerations. Nonetheless, along with the calibrated cost functions, the risk coefficients we use enable us to duplicate the observed land uses for each farm size almost exactly.

suggested an upper bound on ϕ might be as follows: $\phi \leq 5/\sigma_R$, where σ_R is the standard deviation of gross margin. Using data for an average farm of 60 ha and the associated allocation of crops (with 1/3 of the land planted to wheat), and based on yield and price data for 2000-2012, we find $\phi = 0.00009$ as the upper bound. The values for the small, medium and large farms are all well below this threshold.

Moving away from values of ϕ that still retain the observed land allocation towards larger values of ϕ will result in a change in land allocation. As an agricultural producer becomes increasingly risk averse, the primary change in land use is away from wheat and sugar beets towards potatoes and onions, and this is true for each of the three representative farms, as can be seen from Figure 5.2. The relative increase in potatoes and onions compared with wheat and sugar beets is largest for the medium farm, then for the large farm, and finally for the small farm.

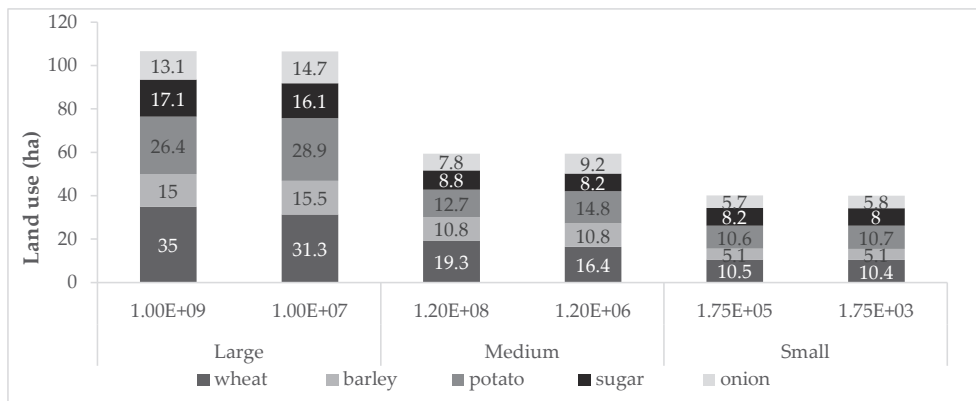


Figure 5.2: Changes in land use: Comparison of a producer's objective of maximizing revenue and minimizing variance for a small, medium and large farm (ha)

5.4 Single farm and green payment

As the CAP changes, payments based on historic entitlements are to evolve into a per-hectare, flat-rate payment that is invariant to crop choice – the Single Farm Payment (SFP). Previously, entitlements were based on the cultivation of specific crops in the reference period (Table 5.2). In the scenarios that follow, we first assume a shift from direct payments tied to crop choice to direct payments independent of crop choice, and then from direct payments independent of crop choice to direct payments with a greening component. In all cases, our objective is to determine impacts on income and land use decisions.

5.4.1 *Single Farm and Greening Payment Scenario*

As part of the 2013 reforms starting in 2015, all producers in the Netherlands will receive a new entitlement based on the size of their operation, which amounts to about €270 per hectare (Dutch Government, 2014).⁶ In addition, 30% of a nation's agricultural support budget is to be reserved for environmentally friendly practices (European Commission, 2014a). For the Netherlands, this implies an additional payment of some €120 per hectare if the producer meets certain greening requirements (Dutch Government, 2014). An arable producer with more than 30 hectares of land must meet three basic practices to qualify for the green payment (RVO, 2015).

1. The producer must maintain permanent grassland, defined as land that has been in pasture for at least five years. In practice, arable farms in the Netherlands only keep 'permanent' grassland if the land is not suited to cultivation, which implies that the farmer's opportunity costs associated with this land are lower than for other cropland. Although grassland is integral to many crop rotation systems, it is generally not held in that state for more than five years. Hence, we do not address this greening option here,

⁶ Note that the SFP based on the payments in Table 1 and the observed land allocation for the average farm (see Table 3 below) would be €282.60 per ha.

focusing instead on the other greening criteria. At a national level, permanent grassland is not allowed to drop below 95% of its 2012 reference level; since we focus on the individual farmer, this objective is also not addressed here.

2. The producer must diversify his crop portfolio. For farms with at least 30 hectares of cropland, this requires that the producer must (1) cultivate at least three crops, with (2) the largest crop planted to no more than 75% of the land and (3) the largest two crops accounting for no more than 95% of land in cultivation.
3. At least 5% of cropped land must be set-aside for purposes such as field margins and buffer strips that are eligible as part of the ecological focus area (EFA). From 2017 this may increase to 7% (European Commission, 2014a).

The exact interpretation of the three basic practices is likely to vary by country, especially concerning the EFA. We assume that farmers have to set-aside 5% of their agricultural land independent of any positive or negative compensation to the area set aside, and that they must satisfy the diversification criteria in order to be eligible for a green payment.⁷

If the farmer meets the crop diversification and set-aside EFA criteria, the SFP will be €390/ha (= €270/ha + €120/ha). In the future, however, farmers might be penalized (witness a reduction in basic payments) if the greening criteria are not met; in essence, the producer would only receive green payments if he complies with crop diversification requirements and satisfies the EFA. To take these conditions and payments into account in our model, the revised revenue equation (2) is written as:

$$R_{k,t} = [p_{k,t} y_{k,t} - c_k(w) + SFP + \delta GP] x_t, \quad \forall k. \quad (13)$$

where *SFP* and *GP* were defined earlier, and δ is a binary variable indicating whether the EFA

⁷ Because the green payment applies to all cropland, it would seem that farmers would always seek to qualify for it. To determine whether it would actually be beneficial for the farmer to qualify, it will be necessary to include these three constraints along with an ‘if condition’ in the programming model that we develop below.

requirement is satisfied ($\delta=1$). In addition, the following three constraints are need to model the greening requirements:

$$x_k \leq 0.75(\bar{X} - x_{efa}), \quad (14)$$

$$x_k + x_i \leq 0.95(\bar{X} - x_{efa}), \quad \forall x_k \neq x_i, \text{ and} \quad (15)$$

$$x_{efa} \geq 0.05\bar{X}, \quad (16)$$

where x_{efa} refers to the area set-aside as part of the ecological focus area. The third crop diversification requirement, cultivating at least three crops, is automatically satisfied via equations (12) and (14), because the largest two crops cannot account for more than 95% of total cultivated area, and the farmer wants to maximize risk-adjusted revenue. Objective (1) is now maximized subject to equations (3)-(6), (12) instead of (2) or (11), and (13)-(15), while retaining the PMP-calibrated cost function and values of the absolute risk aversion coefficient of the base scenario.

5.4.2 *Simulating the effect of a Single Farm and Greening Payment*

As explained in section 5.2, we first simulate a move from direct payments tied to crop choice and then to direct payments that are independent of crop choice. We then simulate a move from direct payments independent of crop choice to direct payments including greening payments. We simulate the results for farms of different sizes with land-use allocations as displayed in Table 5.3. First, rather than the payments based on entitlements indicated in Table 5.1, we now assume that our representative farmers are paid €270/ha, independent of whether they comply with the greening criteria. For the simulations, we assume that changes can only be made to the crop allocation and not to the cropping intensity (e.g., greater use of fertilizer). The land use allocations under different policy scenarios for farms of different sizes are provided in Table 5.6.

Table 5.6: Land use allocation under different policy scenarios for farms of different sizes^a

Crop	Small			Medium			Large		
	Base	SFP	GP	Base	SFP	GP	Base	SFP	GP
Wheat	10.45	10.45	9.72	19.31	19.21	18.02	35.02	34.81	32.61
Barley	5.06	5.06	4.70	10.80	10.74	10.05	14.97	14.88	13.92
Potato	10.55	10.55	10.16	12.68	12.90	12.45	26.37	26.79	25.89
Sugar	8.15	8.15	7.80	8.83	8.63	8.28	17.08	16.69	16.00
Onion	5.72	5.72	5.55	7.79	7.94	7.64	13.09	13.36	12.78
EFA			2.00			2.97			5.33
Total	39.93	39.93	39.93	59.41	59.41	59.41	106.53	106.53	106.53

^a SFP represents the 2013 EU-CAP reform flat-rate or single farm payment of €270/ha and a potential green payment of €120/ha. GP represents the crop allocation if the farmer adopts greening practices.

When moving from payments based on historic reference amounts to the single farm payment without greening criteria, only small changes in land allocation are observed and only for medium and large farms (Table 5.6). For the medium and large farms this leads to a slight decrease in the area allocated to wheat, barley and sugar beet and a slight increase in the area allocated to potatoes and onions. This is as expected, because it indicates a move away from those crops that were eligible for entitlements, towards crops that were not eligible (see Table 5.1). The largest increase, albeit still very limited, is observed for onions (about 2%), but area planted to potatoes also increases by about 1.6% for both medium and large farms. The largest decrease (2.2%) is observed for sugar beets, the crop where a quota regime is still present.

The move from a SFP to one that includes a GP is more profound. In absolute terms, a decrease in land allocation is observed for all crops. Naturally, this is linked to the 5% set-aside which is required to be eligible for green payments. However, some crops experience larger relative decreases than others. A further move away from wheat and barley towards sugar beet, potatoes and onions is observed. The relative shift is about equal between farm sizes, with a slightly larger change for small farms. The crop-diversity requirement of the green component

does not have any effect on the farmer's land allocation because crop diversity was already a common practice among producers of all sizes, a conclusion reached by Mosnier *et al.* (2009) as well.

If a farmer is concerned only with revenue, the shift from payments based on historic entitlements towards SFP, and from SFP towards SFP with GP, would make him worse off (Table 5.7). However, the shift from SFP towards SFP with GP leads to an increase in gross revenue between 7.8% and 8.5%. When accounting for risk however, GP may lead to larger benefits for the farmer in terms of a larger level of utility. Hence, the additional GP income generated is likely to offset the income lost by setting aside 5% of the land; that is, the opportunity costs of setting aside farmland are lower than the GP compensation.

Table 5.7: Changes in gross revenue under different policy scenarios for farms of different sizes.

Crop	Small			Medium			Large		
	Base	SFP	GP	Base	SFP	GP	Base	SFP	GP
Wheat	13,183	12,066	15,181	35,077	33,376	39,314	78,970	62,745	73,609
Barley	6,252	5,701	7,213	18,041	17,088	20,465	32,979	26,029	30,699
Potato	47,675	50,506	52,773	71,769	74,472	77,403	168,214	173,908	179,852
Sugar	32,772	31,027	32,887	39,965	37,726	39,849	87,723	75,791	79,904
Onion	35,596	37,163	38,292	39,970	41,609	43,460	54,101	56,740	60,101
EFA	0	0	779	0	0	1,158	0	0	2,077
Total	135,478	136,463	147,125	204,823	204,271	221,649	421,988	395,213	426,242

The small changes in land allocation we find are in line with the estimated impact of partial decoupling under the 2003 Mid-Term Review; most authors found that it had at most only a modest impact on crop allocation decisions (Helming and Peerlings, 2014; Mosnier *et al.*, 2009; Sckokai and Moro, 2009). Where there was a change, the effects were as predicted – a reallocation of land use away from crop activities that did not receive direct payments under the historical reference scenario, namely, reduced plantings of potatoes and onions.

For the 2013 reforms, we find shifts of a similar magnitude, but then in the opposite direction as incentives no longer disadvantage the planting of these crops. In addition, we find that the introduction of a single flat-rate payment (SFP) along with GP leads to a further relative decline in the area cultivated to cereals. This corresponds with previous research at a regional scale (Balkhausen *et al.*, 2008; Koundouri *et al.*, 2009; Solazzo *et al.*, 2014). The fact that changes are small may also be explained by crop rotation requirements that are inherently incorporated in the PMP calibration.

With respect to the specific greening component measures, diversification measures do not influence a farmer's crop allocation decisions due to crop rotation schemes, while environmental set-aside requirements do substantially alter farm income and the farm plan. For farms of all sizes, the hypothesized green payment of €120/ha appears to compensate for lower revenues caused by set-aside of land, confirming results by Solazzo *et al.* (2014). The EFA requirements will lead to a relatively larger use of the most profitable crops, hence reducing the amount of land devoted to cereals and sugar beets. Furthermore, grassland and set-aside land benefit from the CAP reform, reducing the area allocated to crop cultivation. Taking into account the possibility for land that is not cultivated is therefore of importance in modelling the 2013 CAP-reform (Balkhausen *et al.*, 2008).

5.5 Discussion and Conclusions

Coupled support has slowly been replaced by support linked to land-entitlements with limited coupling, and, finally, to support that is decoupled from the choice of crop activities, with more emphasis on environment-friendly practices (Helming *et al.*, 2010). The objective of this chapter was to analyse different forms of direct payments, including green payments, in terms of their effects on land use (cropping) decisions. More specifically, we analysed if, and under what circumstances, this implies a shift towards more ecologically-sensitive land-use practices for farms of different sizes. Thus, we compared single (flat-rate) farm payments with

and without a greening incentive, as described in the December, 2013 agreement on CAP reform, with the payment system based on historic entitlements. To do so, we developed a mathematical programming model that was calibrated using positive mathematical programming, and maximized utility of different representative producers by selecting various crop (land-use) allocations.

The change from payments based on entitlements to flat rate payments is both crop and farm specific, as also determined by Sckokai and Moro (2009) using econometric analysis. The policy shift is crop specific because previously ineligible crops are now included in the agricultural support scheme. The changes are farm specific because responses to changes in EU farm policies depend on a farmer's utility, with more risk-averse farmers unlikely to modify their cropping decisions and less risk-averse ones more willing to reallocate land among crops. This has been shown by tracing back farm-specific risk coefficients that differ significantly across farm sizes, and thus potentially wealth. Moreover, in the case of a policy change, less risk-averse farmers (owning larger farms) make larger changes to land allocation than more risk-averse ones (with smaller farms).

We assumed farm-specific, constant absolute risk aversion coefficients. This implied that we did not account for wealth effects, where the producer is more willing to plant crops with higher, but riskier returns when his expected gross margin was larger. Instead, we focused on risk-aversion that is inherent to the farm itself. Hence, the change from a historic to a flat-rate payment affects the shadow price of land for some types of farmers more than others, which in turn affects the producer's crop allocation. However, the shift from cereals to potatoes may also be explained as a wealth effect, where the increasing effect of direct payments on income makes producers less averse towards production risk, leading to alterations in the crop portfolio (Koundouri *et al.*, 2009; Sckokai and Moro, 2006; Burfisher and Hopkins, 2003).

Because of the complex and uncertain nature of the direct payments, we had to assume that entitlements, though not entirely crop specific, were based on the land allocated to cultivated

crops eligible for payments in a certain reference period. Hence, our model might overestimate the crop-specific effects. In addition, while the rules and regulations of the new direct payment system are determined at the EU level, their interpretation is country specific, which might make our results less applicable more generally. Finally, research into the biodiversity aspects of crop cultivation is necessary to investigate to what extent the increased shift towards potatoes and onions and away from cereals might offset the ecological benefits obtained from the ecological focus area. Despite these uncertainties, however, the effects on crop strategies found here are likely to remain.

CHAPTER 6. BUSINESS RISK MANAGEMENT: COMPARING THE IMPACTS OF WHOLE FARM AND CROP-SPECIFIC REVENUE INSURANCE¹

Abstract

This chapter aims to investigate the impacts of whole farm and crop-specific insurance on optimal management decisions, taking into account income and risks in crop production in the Netherlands. To this end, a farm management model has been developed that can examine crop-specific and whole farm insurance, where premiums and indemnities are endogenously determined for various insurance options. We use a farm-level analysis where the farmer's objective is to maximize utility, with a farm-specific risk aversion coefficient extracted from PMP calibration. Results indicate that small changes in land allocation are observed when the possibility of whole farm and crop-specific insurance is offered. Land-use changes are larger with crop-specific than with whole farm insurance, with the latter biased towards smaller farms. Furthermore, results are sensitive towards the specification of the risk-aversion coefficient.

¹ Paper by Esther Boere and G. Cornelis van Kooten. Submitted to a peer-reviewed journal.

6.1 Introduction

European Union's policies to reduce intervention in agricultural markets have shifted support payments away from programs that incentivized production towards the support of farm incomes through direct payments and compensation for the provision of public goods (European Commission, 2014a). The EU's December 2013 agreement on reforms to the Common Agricultural Policy (CAP) entailed a further shift away from coupled support, but at the cost of increased volatility in output prices. Increased output price variability does not necessarily imply changes in the level and variance of producers' incomes, however, because income depends on a variety of different types of risks and the correlations among them (Chambers, 2007; Moschini and Hennessy, 2001; Pennings *et al.*, 2010). Nonetheless, if incomes associated with various farm activities are positively correlated, instability of agricultural incomes might well increase. This then requires greater focus on agricultural business risk management (BRM).

BRM can be used to control the possible adverse consequences of uncertainty that may arise from production decisions. Currently a producer in the European Union can adopt several measures to reduce income risk; these include diversifying crop plantings, contracting in forward and futures markets, and purchasing various other financial products such as hail insurance (Finger and Lehmann, 2012). Some of these measures are partly subsidized by governments which intervene to mitigate producers' risks because competitive markets for hedging risk are lacking (see Chambers, 2007; Arrow, 1996). Nonetheless, the recent spikes in agricultural prices resulted in an increased appeal by various EU member states for financial safety nets, including insurance. But if insurance schemes manage the price risk of one output without managing input and other output risks, income risk might well increase rather than decrease on aggregate. This is not the case with multi-product hedging approaches, such as whole farm income insurance. Although eventually not adopted, the proposals of the 2013

CAP reform entailed a risk management toolkit that included whole farm income insurance (European Commission, 2013), which is eligible under WTO rules as a 'green box' item.

The objective of this paper is to analyse and compare the effects that crop-specific and whole farm insurance will have on a farmer's income and land-use (crop allocation) decisions. Payments based on output generally incentivize greater production because the reference revenue used to calculate when a pay-out is triggered depends on a moving average of yield. Insurance may therefore lead to the allocation of more resources to activities with greater volatility of output, and may intensify production resulting in negative environmental effects (Vercammen and van Kooten, 1994; Cafiero *et al.*, 2007).

Insurance strategies depend not only on the degree of price and income uncertainty, but also on the degree of risk aversion perceived by the producer. Farmers are generally considered to be risk averse, which means they will give up some expected income to reduce the possibility of larger losses. The most common way for them to do so is by altering their production plan. This is why producers' preferences for allocating land among crops have often been characterized using an expected utility function (Chavas and Pope, 1985; Coyle, 1999; Oude Lansink, 1999; Sckokai and Moro, 2006). Thus, we assume that the producer's objective is to maximize utility by selecting a variety of cropping (land-use) activities.

The methods used in the literature to examine the influence of insurance measures on production and land use decisions can be broadly divided into two strands. The first involves simultaneous equation models that investigate whether and how acreage responds to different types of insurance schemes (Wu 1999; Wu and Adams 2001; Goodwin *et al.* 2004). The second involves mathematical programming models that examine changes in a farmer's crop portfolio between different insurance products (Turvey 2012). The EU's recent emphasis on insurance implies that econometric approaches based on behavioural functions may be less suited for analysing their impact than other approaches. New restrictions and agricultural

policies might better be modelled using a farm-level crop allocation model that is calibrated using positive mathematical programming (Howitt 1995; Heckelei *et al.*, 2012).

In this study, we use representative farms of three sizes to examine the impacts on production decisions of crop-specific revenue and whole farm income insurance schemes in the Netherlands. We begin in the next section by developing our farm-level model with the current levels of support in place. Then, in section 6.3, we describe the Dutch data we employ, followed in section 6.4 by taking out the current support and modelling the crop-specific and whole-farm revenue scenarios. We report the results in section 6.5, and end with some final observations in section 6.6.

6.2 Farm Business Risk Management Model

Government agricultural programs not only enhance incomes but also reduce exposure to risk. Therefore, in deciding how to allocate her land among different uses, the farmer takes into account the availability of government support payments and crop insurance programs. Our purpose is to determine the potential effect of crop-specific and whole farm income insurance on the way the farmer allocates his land to alternative crop activities. We do this using a farm-level crop allocation model.

We focus on the variability in a farmer's gross margins and model it following an approach suggested by Turvey (2012). As opposed to minimizing variance used by Turvey (2012), we maximize the producer's utility function using mean-variance analysis whereby expected income is adjusted for risk. We define risk as variance in the gross margin of the crop portfolio adjusted by the producer's absolute risk aversion coefficient (denoted ϕ). Gross margins are based on historic crop yields, prices and identifiable variable costs. Using empirically-determined parameters, we employ Monte Carlo simulation to obtain 1,000 possible gross margin outcomes (iterations). The gross margin is also adjusted by accounting for the per

hectare payment based on historic entitlements. Variance is then calculated over the adjusted gross margin.

We begin by constructing a base farm-level crop allocation model that includes a direct payment (€/ha) that varies by crop and is assumed to be in place before the 2013 CAP reforms go into effect (Helming *et al.*, 2010). We discuss how we calibrate our crop allocation model using positive mathematical programming (PMP), and then describe how the model needs to be modified to take into account differences between crop-specific and whole farm insurance.

6.2.1 Base Model and Flat-Rate Payments

We assume that producers maximize income while accounting for risk in their production decisions. Representative arable farmers with fixed amounts of land and facing exogenous input and output prices aim to maximize expected utility from total revenues by allocating land to various crops. Currently, producers receive a direct payment per hectare that varies by crop based on historic entitlements. However, a flat-rate payment was introduced with the 2015 crop year; it provides the same payment regardless of the crops planted by the producer, and is referred to as the single farm payment (SFP). Based on prior payments based on historic entitlements and crop allocations in our 2012 base year, the average direct payment was €310 per hectare (Doorn *et al.*, 2011).

To analyse the crop allocation decision, we develop the following model:

$$\text{Maximize } U = \sum_{k=1}^K E[R_k] - \frac{1}{2} \phi \sigma^2 \quad (1)$$

Subject to:

$$R_{k,t} = [p_{k,t} y_{k,t} - c_k(w) + SPS_k] x_k, \quad \forall k \quad (2)$$

$$\sigma^2 = \sum_{k=1}^K \sum_{i=1}^K [x_k \times CV(R_k, R_i) \times x_i] \quad (3)$$

$$CV(R_k, R_i) = \frac{1}{T} \sum_{t=1}^T (R_{k,t} - E[R_k])(R_{i,t} - E[R_i]) \quad \forall k, i \quad (4)$$

$$E[R_k] = \frac{1}{T} \sum_{t=1}^T R_{k,t} \quad \forall k \quad (5)$$

$$\sum_{k=1}^K x_k \leq \bar{X} \quad (6)$$

U represents the producer's utility; $\sum E[R_k]$ is the expected total revenue minus variable costs from crop production; φ is the risk aversion coefficient, that takes the form $-\frac{U''(I)}{U'(I)}$, where I refers to the farm household's income;² σ^2 is the variance associated with the total crop portfolio; $p_{k,t}$ and $y_{k,t}$ represent the respective output price and yield for crop k in period t ; $c_k(w)$ is the per unit-area variable cost of producing crop k as a function of exogenously-determined input prices w ; and SPS is the flat-rate payment based on historic entitlements (€/ha). Further, $CV(R_k, R_i)$ refers to the covariance matrix, where R_i and R_k are the respective realized gross margin to crops i and k , and $E[R_k]$ is the farmer's expected gross margin (€/ha) from planting crop k ; x_k denotes the number of hectares allocated to produce crop k ; and \bar{X} represents the total area (ha) the farmer has available to allocate to crops. There are K crops that can be planted in any given period and there are T periods. T may refer to historic revenues (calibration phase) or to the outcomes from a Monte Carlo simulation (simulation phase).

Equation (2) calculates the farmer's gross margin accruing to each crop in each period given the allocation of land to crops, which is endogenously chosen in the model. SPS is included in (2) but fixed production cost is not because fixed costs are part of the PMP term (as explained

² When the utility function takes an exponential form, maximizing utility with normally distributed consumption results in a standard mean-variance objective as follows (McCarl and Spreen 2004, p.14-18): $U = E[R] - \frac{\varphi}{2} \sigma^2$. $U = E[R] - \frac{\varphi}{2} \sigma^2$. Some authors specify utility as a function of consumption or wealth.

next). Equation (3) specifies the risk associated with the total crop portfolio, while equation (4) provides the variance-covariance matrix. Equation (5) calculates the expected gross margin that accrues to each crop over all periods (simulations). Finally, constraint (6) indicates that the farmer's cultivated area does not exceed the available area. In each period, the producer must decide how to allocate her \bar{X} hectares among the K different crops so as to maximize utility over the total set of crops.

6.2.2 Model Calibration

The usual PMP model starts with an objective function that maximizes the overall gross margin from crop activities subject to constraint (6) and added calibration constraints. Subsequently, the linear objective function is adjusted to account for nonlinearities due to such things as differences in soil quality and the need to rotate crops to mitigate fungi and disease (Heckelei *et al.*, 2012). We specify gross margins as a function of land use as follows: $R_k(x_k) = p_k y_k - c(x_k) = p_k y_k - (\alpha_k x_k + \frac{1}{2} \beta_k x_k^2) + SFP_k x_k$, with $c(x_k) = (\alpha_k + \frac{1}{2} \beta_k x_k) x_k$ an assumed quadratic cost function and SFP_k the direct payment based on historic entitlements. The shadow price is specified as the difference between the marginal and average cost, $\lambda_k = \frac{1}{2} \beta_k x_k$. In the third step, the objective function is revised to take into account the following quadratic cost function:

$$\sum_{k=1}^K R_k = \sum_{k=1}^K [p_k y_k - (\alpha_k + 0.5 \beta_k x_k) + SFP_k] x_k, \text{ and the calibration constraints are removed.}$$

To calibrate the model using PMP is somewhat more complicated when the objective is to maximize expected utility rather than the overall expected gross margin. One should also calibrate the absolute risk aversion parameter, but the methods for doing so (Petsakos and Rozakis, 2011, 2015) require the assumption of decreasing absolute risk aversion (DARA) as opposed to constant absolute risk aversion (CARA). Further, it requires the specification of an initial level of wealth so that DARA can change in response to the farmer's cropping choices. In the current application, we use a farm-specific risk-aversion coefficient based on the

assumption that a producer's total wealth is unlikely to change dramatically from one crop year to the next, in which case the farmer's risk aversion is best characterized by constant rather than decreasing absolute risk aversion. Moreover, we assume different farmers with varying degrees of risk aversion. In order to do so, an exponential utility function and normal distribution of wealth are required. Therefore, once the cost parameters from the linear PMP program are obtained, the objective function is set to maximize expected utility. The related risk-aversion coefficient ϕ is then varied for each representative producer in step 3 of the PMP model by iteratively increasing its value to the point where it begins to impact the calibrated (observed) crop allocation (see Chapter 5). The risk coefficient is then set to the value where it just does not affect crop allocation. This results in risk aversion coefficients of 1.2×10^{-6} , 1.2×10^{-6} and 0.4×10^{-6} for small, medium and large farms respectively.

Given the parameterized nonlinear objective function, it is now possible to simulate changes to the policy variables. The objective function in equation (1) then includes calibrated costs in $E[R_t]$ and the maximum possible value for ϕ that still produces the observed crop allocation.

6.3 Data and Descriptive Statistics

Our study focuses on representative Dutch arable farms of three different sizes that have a mixed crop portfolio. Data for the period 2000 through 2012 were obtained from the Farm Accountancy Data Network (FADN), but because the FADN employs a sample of farms for each year, it was not possible to identify historic data for any representative farm size that we might examine. Thus, we took a sample of farms in each size category to establish historic yields and costs for the representative farms. The data were then used to measure annual variations in producer yields and costs. Costs of seed, pesticides, fertilizer, energy and other variable costs for various crop activities were used to construct per ha variable costs.

Since prices are not farm-specific, these are obtained from outside sources. Future prices are often used to establish expected farm revenues. However, neither monthly nor futures

contract prices were available for all crops in the Netherlands. Therefore, to reduce price coverage to within-season fluctuations, as is common practice (Meuwissen *et al.* 2003), we used quarterly producer prices covering the period 2000 through 2012. For onions, wheat and barley, we aggregated monthly producer prices to the quarterly level. For sugar beets and potatoes, we calculated quarterly prices based on the yearly producer price of the specific crop and quarterly nominal indices obtained from Eurostat (2014).

Given farm-specific yields, costs and external price data, gross margins were calculated for each crop activity for 2012, and reported in Table 6.1 for each representative farm size. Also reported in Table 6.1 are the observed average 2012 crop allocations for the representative farms. Notice that potatoes and onions provide the greatest gross margins, but also the most volatile crops; indeed, 2012 was a very good year for these crops. As a result, simulated average margins based on farm-specific historic yields multiplied by national-level quarterly prices will thus be lower compared with the gross margins observed in Table 6.1. Consequently, based on our simulations, we reduced the gross revenues for all root crops (potatoes, sugar beets and onions) by €2,000 per hectare compared to the data reported in Table 6.1 for the PMP calibration phase. From the PMP calibration, we find crop-specific costs as a quadratic function of land allocated to the activity, and use these cost functions in the policy analysis. Although the average cropping plan differs from one producer to another, farmers in the Netherlands tend to allocate their land first to potatoes and then to sugar beets, although they need to consider the need to maintain crop rotations to mitigate fungi and disease.

It has long been believed that farm size is negatively related to risk aversion – that perceived risk decreases when farm size increases. This would lead larger farms to plant a greater proportion of their available area to crops with greater income variation but higher expected gross margin. This is a major justification for our use of representative small, medium and large farms.

Table 6.1: Yield, price, costs and gross margin by farm size in 2012.

Crop	Observed ha	Yield (1000 kg/ha)	Price (€/1000 kg) ^{a)}	Variable cost (€/ha)	Direct payments	Gross revenues (€/ha)	St. Dev. Gross Revenues
SMALL							
Wheat	10.45	7.84	242.37	911.59	377.50	1900.20	172.47
Barley	5.06	6.31	226.87	564.34	377.50	1431.08	80.80
Potato	10.55	38.71	192.50	2174.90	0	7451.62	1186.78
Sugar	8.15	77.36	55.97	1160.29	687.00	4330.17	486.12
Onion	5.72	74.85	117.57	2388.67	0	8799.82	3199.29
Total	39.93						
MEDIUM							
Wheat	19.31	8.61	242.37	647.25	377.50	2086.83	190.02
Barley	10.8	7.55	226.87	489.11	377.50	1711.71	110.26
Potato	12.68	42.49	192.50	2357.02	0	8180.25	1030.02
Sugar	8.83	80.36	55.97	1080.62	687.00	4498.20	269.68
Onion	7.79	62.97	117.57	2184.60	0	7403.49	1834.69
Total	59.41						
LARGE							
Wheat	35.02	8.86	242.37	593.23	377.50	2147.42	190.02
Barley	14.97	7.35	226.87	387.34	377.50	1667.93	110.26
Potato	26.37	45.57	192.50	2253.42	0	8772.78	1030.02
Sugar	17.08	79.45	55.97	993.48	687.00	4447.16	269.68
Onion	13.09	57.93	117.57	2227.38	0	6810.6	1834.69
Total	106.53						

^{a)} Prices are average national quarterly prices, yields and costs are farm-specific.

6.4 Insurance Programs

Government participation in agricultural insurance is considered to fall into the WTO's 'green box' if the following conditions apply: (i) insurance is based on an income shortfall relative to a reference level; (ii) indemnities do not relate to the volume of production or input use; and (iii) income protection is triggered when income falls to 70% or less of the reference level and

the indemnity is no more than 70% of the difference (OECD 2011; Coppens, 2014). Given this guiding principle, we assume that the producer receives restitution for up to 70% of lost income if total income from the entire crop enterprise falls below 30% of the reference level. We consider two types of revenue insurance to meet these requirements: (1) whole farm insurance and (2) crop-specific insurance. For both types, we assume that the current level of support no longer exists.

6.4.1 Whole Farm Insurance

Now we assume that there is a target or reference gross margin for the whole farm that is denoted M , which is the expected gross margin across all random states T . Premiums and indemnities are determined endogenously. With whole farm insurance only, constraint (2) is now written as (see Turvey 2012):

$$R_t = \sum_{k=1}^K (E[R_k] - \frac{1}{2} \varphi \sigma^2) + Z \times \text{Max} \left(0, 0.7M - \sum_{k=1}^K (p_{k,t} y_{k,t} - c_k) x_k \right) - \frac{\delta}{T} \sum_{t=1}^T \text{Max} \left(0, 0.7M - \sum_{k=1}^K (p_{k,t} y_{k,t} - c_k) x_k \right) \quad (7)$$

where $M = \sum_{k=1}^K \sum_{t=1}^T (p_{k,t} y_{k,t} - c_k) \frac{T}{K}$ is the whole-farm reference level of income; only 70% of M would potentially be covered and then only if actual revenue falls by more than 30% of the reference level. The dummy variable Z is thus defined as:

$$Z = \begin{cases} 1 & \text{if } \sum_{k=1}^K R_{k,t} x_k < M \quad (\text{payout}) \\ 0 & \text{if } \sum_{k=1}^K R_{k,t} x_k \geq M \quad (\text{no pay-out}) \end{cases} \quad (8)$$

where $\sum_{k=1}^K R_{k,t} x_k = \sum_{k=1}^K (p_{k,t} y_{k,t} - c_k) x_k$.

In equation (7), $\text{Max}\left(0, 0.7M - \sum_{k=1}^K (p_{k,t}y_{k,t} - c_k)x_k\right)$ is the WFI indemnity in a given state of nature t , and $-\frac{\delta}{T} \sum_{t=1}^T \text{Max}\left(0, 0.7M - \sum_{k=1}^K (p_{k,t}y_{k,t} - c_k)x_k\right)$ is the premium paid for WFI, where δ again represents the share of the premium that the farmer pays with the government subsidizing the remainder. The indemnity is based on the sum of the crop enterprises' differences between realized and expected gross margin.

To find the optimal allocation of crops under insurance, we solve the constrained optimization problem given by equations (1) through (6), but with (2) replaced by (7) or (9) depending on whether crop-specific or whole farm income is modelled, respectively.

6.4.2 Crop-Specific Revenue Insurance

Now we assume that agricultural producers have the option to insure the gross margin for any specified crop. Following Turvey (2012), we assume that this option is available for each of the individual crops in the model, and that a shortfall of at least 30% in targeted gross margin receives a payment up to 70%. We assume that there is a similar target or reference margin for each crop, denoted M_k , which is the expected gross margin for each crop across all random states T . Prior to setting an insurance premium, the total set of cropping activities has to be selected. This results in the endogenous setting of premiums and indemnities.

With crop-specific insurance, the objective function specified in equation (1) can now be written as:

$$R_t = \sum_{k=1}^K (E[R_k] - \frac{1}{2} \varphi \sigma^2) + Z_k \times \text{Max}(0, 0.7M_k - (p_{k,t}y_{k,t} - c_k)x_k), \quad (9)$$

$$-\frac{\delta}{T} \sum_{t=1}^T \text{Max}(0, 0.7M_k - (p_{k,t}y_{k,t} - c_k)x_k)$$

where the dummy variable is specified as:

$$Z_k = \begin{cases} 1 & \text{if } \sum_{k=1}^K R_{k,t} x_k < M_k \quad (\text{payout}) \\ 0 & \text{if } \sum_{k=1}^K R_{k,t} x_k \geq M_k \quad (\text{no payout}) \end{cases}, \quad (10)$$

where $R_{k,t} x_k = (p_{k,t} y_k - c_k) x_k$. M_k signifies the reference gross margin associated with crop k , while $\text{Max}(0, 0.7M_k - (p_{k,t} y_{k,t} - c_k) x_k)$ is the pay-out to crop enterprise k when outcome t occurs as the realized gross margin is 70% or less of the reference margin. Both the realized gross margin and the reference gross margin are calculated from Monte-Carlo iterations. The premium the farmer pays for hedging crop k is given by $\frac{\delta}{T} \sum_{t=1}^T \text{Max}(0, 0.7M_k - (p_{k,t} y_{k,t} - c_k) x_k)$, where δ represents the share of the premium that the farmer pays with the government subsidizing the remainder. It is assumed that the rate of subsidy is the same across all crops.

6.4.3 Gross Margin Scenarios

Following Turvey (2012), we generate random gross margins for representative farms of different sizes using Monte Carlo simulation, thus explicitly accounting for trends and variability in prices and yields. We generate 1,000 potential outcomes (states of nature) for each crop alternative used in the current application. In determining gross margins, the observed average costs of planting, tending and harvesting are employed; these costs are fixed at the observed value (c_k^0) when calculating insurance premiums and indemnities. For simulated gross margin scenarios, we employ historic gross revenues as a measure for price per hectare of land in our simulations. Although the decision for crop allocation, and therefore the related yield, is made before output prices are known, prices and yields influence each other. In order to take correlations between prices and yields into account, we simulate the generation of revenues (€ ha⁻¹) as follows:

$$R_{k,t} = ((p_k y_k)_t - c_k^0) x_k, \quad t = 1, \dots, T, \forall k, \quad (11)$$

where $R_{k,t}$ refers to the crop-specific gross margin from planting crop k under random outcome t , with each of gross revenue $p_k y_k$ randomly determined and $x_k = 1, \forall k$.

The distributional assumptions pertaining to prices (Goodwin *et al.* 2003) and yields (Claassen and Just, 2011; Coble and Dismukes, 2008; Paulson and Babcock, 2008) have been widely researched. There is a broad consensus that prices and yields have to be de-trended to exclude inflation and technology bias from estimates of the underlying probability distribution (Cooper, 2010), although ongoing debate continues regarding the proper way to do this. We regress prices and yields on time using OLS as this is common practice (Coble and Dismukes, 2008; Cooper, 2010; Sherrick *et al.*, 2004).

We then estimate gross revenues using geometric Brownian motion (GBM) with a mean-reverting process – rather than a normal random walk, there is the tendency for prices to return to their mean level, but at a speed determined by the reversion rate. The Ornstein-Uhlenbeck or Vasicek process, which is commonly used to model prices, is used to simulate this stochastic process that takes the following form:

$$dp_t = \theta (\mu - p_t) dt + \sigma dW_t, \tag{12}$$

where $\theta(\mu - p_t)$ is the deterministic part with drift $(\mu - p_t)$, where μ is the long-run equilibrium or mean value, and σdW_t is the stochastic part where σ is the diffusion parameter. Brownian motion is given by dW_t which follows a normal distribution $N(0,t)$; θ is the speed of mean reversion, or the speed at which the process reverts towards its mean value; and σ is the degree of volatility and $\frac{1}{2} \sigma^2 / \theta$ is the long-term variance. The estimated values for θ , μ , and σ are provided in Table 6.2 by crop and representative farm size. As can be observed from the table, all mean prices are slightly lower than the observed average prices in the base year.

The 1,000 possible per hectare crop-specific gross margins outcomes for each crop are shown in figure 6.1 for the medium sized farm. The simulation results provide the expected returns and variances that are then used to analyse the crop-specific and whole farm insurance. As

can be observed from the figure, and in line with Tables 6.1 and 6.2, both the revenues and the volatility are much larger for potatoes and onions compared with wheat, barley and sugar beet. Clearly, gross margins for grains tend to be much lower and less volatile, compared with those of root crops, with the exception of sugar beets. Sugar beets are generally sold under contracts to sugar producers, thus explaining their lower returns and volatility of returns. Based on the gross revenue, farmers are likely to plant onions and potatoes over the other crops because, even at their lowest revenue, these crops are more profitable than the other crops. However, also costs are higher for these crops. Moreover, it is still necessary for the farmer to plant cereals for reasons unrelated to income and income risk, namely, for reasons related to agronomic needs, such as crop rotations that mitigate disease and fungus.

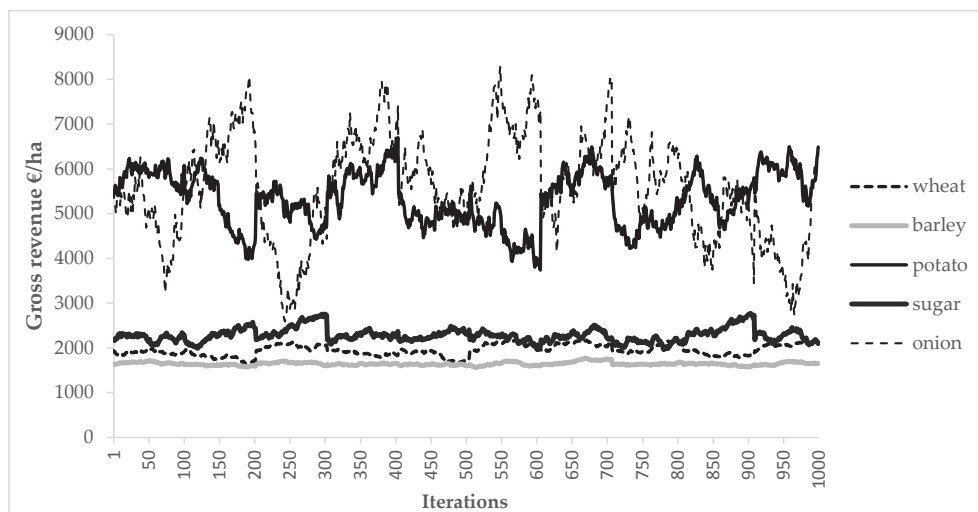


Figure 6.1: Crop-specific Monte-Carlo gross margins for the medium farm (€/ha).

Table 6.2: Estimated parameters to calculate farm-specific gross revenue scenarios

SMALL	θ	μ	σ
Wheat	0.36	1645.46	138.64
Barley	0.34	1353.44	66.27
Potato	0.78	5360.22	1446.3
Sugar	0.34	2711.68	303.59
Onion	0.45	6581.14	3086.52
MEDIUM			
Wheat	0.34	1958.56	152.17
Barley	0.34	1645.42	74.03
Potato	0.79	5361.83	1272.42
Sugar	0.65	2284.91	309.13
Onion	0.63	5597.97	2093.89
LARGE			
Wheat	0.34	1958.18	251.78
Barley	0.34	1645.42	159.82
Potato	0.79	5861.83	1602.13
Sugar	0.65	2284.91	244.09
Onion	0.63	5491.67	2958.18

6.5 Results

We now examine the producer's impact on land allocation and willingness to pay for crop-specific and whole farm insurance. In all cases, our objective is to determine impacts on land use decisions.

6.5.1 Base Model

The various scenarios are simulated in R with calls to GAMS.³ We begin by maximizing the net revenue of the representative farmer described in Tables 6.1 and 6.2 subject to technical

³ R is a statistical programming language (<http://www.r-project.org/>) and GAMS refers to the General Algebraic Modeling System (Rosenthal, 2008).

and observed land-use calibration constraints. Gross margins are given for each crop as price \times yield minus average cost, using the data in Table 6.1. Then, using the shadow prices from step 1 of the PMP process, we discover the quadratic variable cost function for each crop and, upon substituting these into the objective function in lieu of observed average variable production costs, we obtain the observed land allocation choices.

Initially, only four PMP activities are calibrated as barley continues as a non-marginal (linear) activity for all farm sizes as its calibration constraint was not binding ($\lambda_b=0$). Therefore, it is necessary to obtain outside information for barley in order to distinguish between average and marginal cost. Following Howitt (2005, pp.88-91), we take the elasticity of land supply with respect to the price of the crop: $\eta_s = (\partial q/\partial p) (p/q) = (\partial x_b/\partial MC_b) (p_b/x_b^o)$, where x_b^o is the observed land in barley and p_b is the output price for barley. The adjustment at x_b^o that is added to the LP average cost to obtain a nonlinear cost function is defined as: $Adj = MC - AC = \frac{1}{2} \beta_b x_b^o = p_b/2\eta_s$. Adjusting for barley also changes the values for the other crops as follows: $\hat{\lambda}_k = \lambda_k + Adj$. Based on a previous study using the same time period and study area, we choose a value for the elasticity of barley with respect to land (η_s) of 0.174 (see Chapter 2). The farm-specific results for $\hat{\lambda}_k$, α_k and β_k , which are obtained after re-calibration of the PMP model, are presented in Table 6.3, while the observed land uses are provided in Table 6.1.

Table 6.3: Shadow Prices and PMP Calibrated Marginal Cost Functions at Final Calibration

Crop	Small			Medium			Large		
	λ	α	β	λ	α	β	λ	α	β
Wheat	4235	-3323	810	5136	-4488	532	5067	-4473	289
Barley	4114	-3549	1627	4919	-4430	911	4793	-4406	641
Potatoes	6451	-5276	1223	6869	-5512	1083	6789	-5536	515
Sugar beets	4655	-3494	1142	5296	-4216	1200	5200	-4206	609
Onions	5577	-4189	1950	6481	-5296	1664	6254	-5027	956

To determine the sole impact of insurance schemes on crop allocation, we first remove the support measures currently in place. These are the direct payments that are currently based on crop-specific historic entitlements (see Table 6.1). The abolition of payments based on historic reference amounts results in only small changes in land allocation (Table 6.4). For the medium farm, this leads to a decrease in the area allocated to wheat and barley, and an increase in the area allocated to potatoes, sugar beets and onions. This is as expected because it indicates a move away from those crops that were eligible for entitlements towards crops that were not eligible (see Table 6.1). The only exception is sugar beets, which received support in the base scenario, yet also leads to a slight increase in crop allocation for large farms when direct payments are abolished. This may be related to the low variability observed in revenues for sugar beets and the relatively large revenues for this crop.

Table 6.4: Crop allocation without historic reference payments compared to the base scenario

Crop	Small		Medium		Large	
	Base	Without direct payments	Base	Without direct payments	Base	Without direct payments
Wheat	10.45	9.52	19.31	18.69	35.02	30.11
Barley	5.06	4.71	10.80	10.51	14.97	14.98
Potatoes	10.55	10.92	12.68	13.23	26.37	24.76
Sugar beets	8.15	7.85	8.83	8.34	17.08	21.85
Onions	5.72	6.92	7.79	8.64	13.09	14.80

6.5.2 Whole Farm Insurance

Whole farm insurance provides a producer with a certain income if gross margin falls below 70% of the farm-specific reference income. This may make the farmer less risk-averse and thereby lead her to choose a crop allocation that yields higher returns but is likely to be more volatile. In this application, these are potatoes and onions. The subsequent policy interest is to analyse the extent by which farmers will alter their crop allocation if their income is partly

secured. Without any subsidy on WFI, there will be no change in crop allocation, because what the farmer has to pay as insurance indemnity is equal to the size of his pay-out. At an insurance pay-out of 70% and a subsidy share of 0.7, the resulting crop allocation mix of the producer is depicted for the small, medium and large farm in figure 6.2.

As can be seen from figure 6.2, a small increase in potatoes is observed for the small and medium farm. For the large farm, the shift in land allocation mainly takes place from wheat to sugar beets. For the small farm, the changes in land allocation are only captured by the effect of the removal of historic reference payments. This is due to our definition that income must fall below 70% of reference income in order for the farmer to receive insurance. Changes in crop allocation for the small farm with changes in the reference trigger for receiving a pay-out are indicated in figure 6.3. As can be observed from the figure, only when the trigger constitutes 80% of the reference margin does the farmer change his land use. It would appear, therefore, that the trigger must be set to at least 80% before the small farmer would be willing to participate in whole farm insurance.

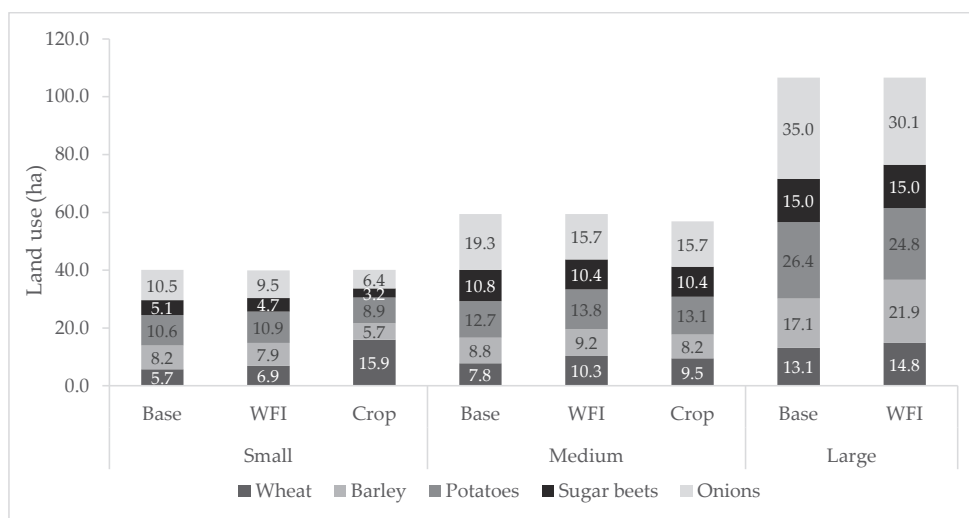


Figure 6.2: Crop allocation plan for a small, medium and large farm under Whole Farm Insurance, compared with the base allocation.

The case for the medium-sized farm is illustrated in figure 6.4. Changes in land allocation are more drastic and observed at much lower thresholds of the trigger. When the trigger is set at 60%, the farmer starts changing land use and, importantly, would be willing to participate in a whole-farm insurance scheme. As the threshold trigger ratio increases from 0.6 towards 0.8, the crop allocation changes more dramatically than for small farms; less wheat is planted in favour of more onions, sugar beet and potatoes.

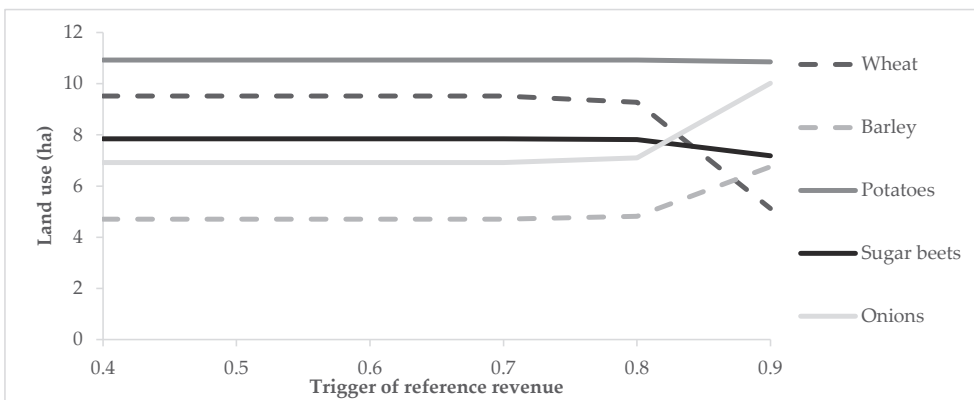


Figure 6.3: Changes in crop allocation for the small farm when the trigger of reference revenue changes from 0.4 to 0.9.

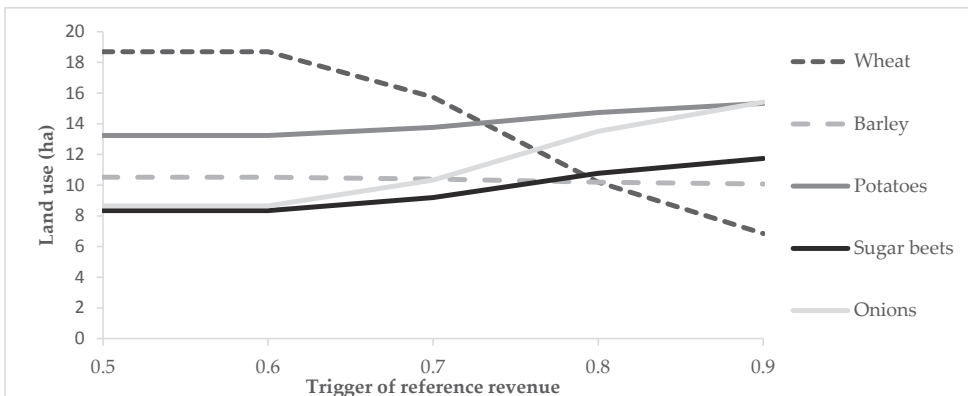


Figure 6.4: Changes in crop allocation for the medium farm when the trigger of reference revenue changes from 0.4 to 0.9.

The large farm will never participate in the insurance scheme. This can be observed from the fact that land allocation under WFI is the same as land allocation with direct payments removed for the large farm. This may be related to the lower level of risk aversion for the large farm, suggesting that the larger agricultural producer is less affected by the variability of gross margins, and would only plant wheat and barley for their agronomic benefits, say. The changes to crop allocation due to WFI do not only reflect a move towards those crops that potentially yield higher revenues, but also relate to the farmer's risk-aversion and her production constraints. Changes to land allocation are therefore highly farm specific. WFI may therefore be biased towards smaller farms. This result is in line with Finger and Benni (2014) who find that the introduction of an Income Stabilisation Tool (IST) will reduce income inequality.

6.5.3 *Crop-specific Revenue Insurance*

Crop specific insurance gives the farmer the possibility to insure only one or a few crops instead of the whole farm allocation plan. The changes in land allocation induced by crop-specific insurance are therefore larger than that of whole farm insurance, as can be observed from figure 6.5. A small farm will further decrease its allocation of land to wheat and barley. The additional hectares of land are mostly converted into onions, the most volatile crop. In fact, it will also substitute part of its land from potatoes to onions. However, all crops will still be cultivated.

For the medium farm, crop allocation also moves away from wheat and barley. The allocation of land to potatoes will increase with about 0.5 hectares compared with the base scenario, but will decrease with about the same size compared with WFI. Here, the area allocated to cereals remains at 46.8 percent of total land allocation however. Also for the medium farm, the additional hectares of land will move towards the cultivation of onions.

With crop specific insurance, also the large farm experiences changes in land allocation. A move away from barley towards potatoes is observed. The move towards these crops is logic given the crops that are triggered for pay-out, as can be observed in Table 6.5. As expected, especially onions and potatoes receive a large share of pay-outs. However, this also implies that they have the highest premium.

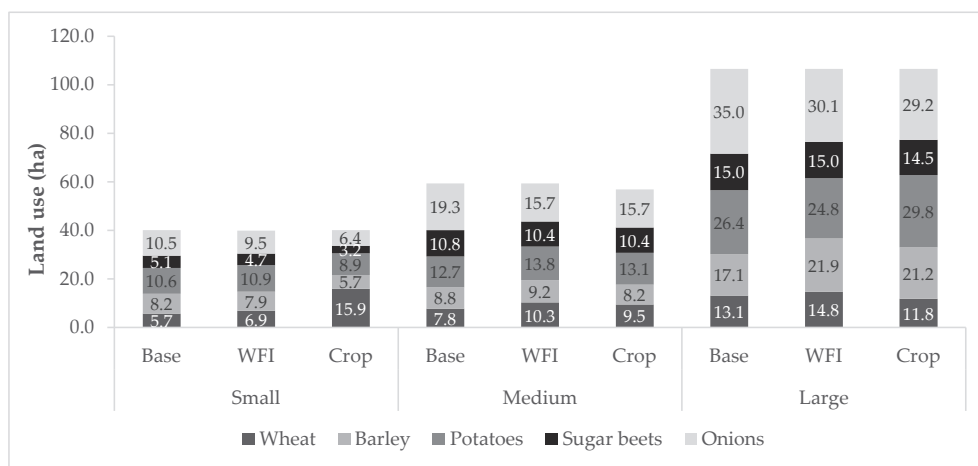


Figure 6.5: Crop allocation plan for a small, medium and large farm under Crop-specific Revenue Insurance, compared with the base and WFI allocation.

Table 6.5: Number of times of trigger and related crop-specific premium.

Crop	Small		Medium		Large	
	Trigger	Premium	Trigger	Premium	Trigger	Premium
Wheat						
Barley						
Potatoes	280	92.97	294	106.82	325	120.13
Sugar beets	64	9.14	90	19.37		
Onions	840	519.84	866	87.30	49	106.07

The fact that with both whole farm and crop specific insurance only small changes in land use are observed may also have to do with crop rotation requirements. In the 1st-stage of the PMP

calibration, the linear objective function was adjusted to include nonlinear terms (Heckelei *et al.*, 2012). One of the main reason for nonlinearities are crop rotation requirements, which are physical attributes of the land and therefore cannot be measured. The main crops with large revenue and high volatility, onions and potatoes, will take increasing marginal costs for each additional hectare of land that is planted with them when they move closer to the specific boundary set by crop rotation requirements (Howitt, 1995). The PMP calibration therefore causes a smooth supply response leading to a continuous, but slow change towards these crops with increases in the trigger for pay-out under various insurance mechanisms. This way, over-specialisation and unrealistic responses in land uses, implying mono-culture of onions or potatoes, is offset (Röhm and Dabbert, 2003).

Neither under WFI, nor under crop-specific insurance does a change to the proportion of the subsidy paid by the government (δ) change the production decisions of the farmer once he has decided to participate in the respective insurance program. This is because the amount is small compared to the producer's gross margins, leading the effect of the premium subsidy on changes to land allocation to be negligible. However, in the current model, it is unlikely that an insurance program such as WFI will exist without government support because of the endogenous setting of pay-outs and premiums. Hence, if farmers know the parameters of the whole farm insurance policy, it is possible for them to change their farming practices to optimize the insurance decision. Without subsidies, this may lead farmers to only choose for crop insurance schemes in case of moral hazard where the environmental conditions discourage production, but the insurance schemes have the opposite effect (Rude and Ker, 2013). A way to include the option of moral hazard is to deviate the reference revenue from the actual revenue outcomes of the Monte Carlo iterations. In that case, what the principal (government) can observe differs from what the agent (farmer) experiences. However, this does not lead to an endogenous setting of pay-outs and premiums anymore.

6.5.4 Sensitivity Analysis for the risk aversion coefficient

In this study, we assume that in order to incorporate risk and uncertainty into the farm model, a farmer maximizes expected utility, instead of total gross margin, from crop production. We have iteratively chosen values for ϕ until it started to impact crop allocation. Instead of Petsakos and Rozakis (2015) who used a decreasing absolute risk aversion (DARA) parameter with a logarithmic function, this study used a constant absolute risk aversion (CARA) parameter with an exponential utility function. We therefore first calibrated cost functions using the standard PMP approach based on an LP model where the objective is to maximize overall gross margins, and subsequently adjusted the level of ϕ until crop-allocation changed in order to determine a starting value.

However, it might still make sense to examine the influence of different levels of ϕ on farm specific crop allocation. In their seminal paper, McCarl and Bessler (1989) suggested an upper bound on ϕ might be as follows: $\phi \leq 5/\sigma_R$, where σ_R is the standard deviation of gross margin. This leads to values for ϕ of 1.35×10^{-4} , 1.45×10^{-4} and 7.8×10^{-5} for the small, medium and large farm respectively. We therefore check what these values would do to crop allocation. Table 6.6 shows the changes in crop allocation in ha with the farm-specific upper bounds for ϕ compared with the values for ϕ obtained from the PMP-procedure.

Table 6.6: Change in crop allocation for varying levels of risk aversion coefficient^{a)}

Crop	Small		Medium		Large	
	WFI	Crop	WFI	Crop	WFI	Crop
Wheat	0.38	0.05	-0.31	0.13	2.18	0.18
Barley	0.19	-0.01	0.22	0.09	-0.04	0.08
Potatoes	-0.07	-0.05	-0.05	-0.30	2.57	-0.07
Sugar beets	0.25	0.06	0.43	0.12	-3.39	0.13
Onions	-0.86	-0.05	-0.32	-0.03	-1.31	-0.34

^{a)}The risk-aversion coefficient changes from 1.2×10^{-6} , 1.2×10^{-6} and 0.4×10^{-6} to 1.35×10^{-4} , 1.45×10^{-4} and 7.8×10^{-5} for the small, medium and large farms respectively.

When the farmer has a larger risk-aversion coefficient, she chooses less volatile cropping activities compared with a lower risk-aversion coefficient. However, the move towards more volatile crops compared with the base scenario is still present.

6.6 Discussion and Conclusions

Changes in agricultural policies have influenced both the level and the variance of farm incomes as natural volatility in yields is combined with increased instability in output prices, which is partly attributable to the European Union's reforms. Increased volatility leads to more price and income uncertainty for producers about the difference between the actual and expected output price and to a change in the shadow price (value) of agricultural land. This uncertainty may differ by activity, while the degree of perceived uncertainty may differ across farms. The objective of this Chapter was to analyse and compare potential crop-specific and whole farm insurance programs. This was achieved by employing a mathematical programming model that endogenously determined crop allocations under different insurance schemes. Using data of Dutch arable producers of different sizes we investigated optimal crop portfolios, where insurance premiums and indemnities depend on the crop allocation chosen but, at the same time, the crop allocation depends on the type of insurance provided.

For a risk-neutral producer, uncertainty and therefore insurance possibilities will not influence her production decisions. For a risk-averse producer, production activities with a high expected output price and low profit variability are preferred. WFI takes away part of the insurance and therefore leads to more allocation of crops with a higher volatility. All producers in our study are, albeit to different extents, risk-averse. When faced with increased volatility in output prices, they are more likely to switch to less volatile production activities. Depending on the change in shadow price of land, the difference between the actual and expected output price and the level of risk aversion, the respective farmers of our study adjust

their land allocation decisions. We find that effects of whole farm insurance are larger for smaller farms than for larger farms, whereas the effects of crop-specific insurance are not. This is inherent to the higher risk-aversion coefficient of these farms. Hence, if from a policy perspective the aim is to reduce inequality amongst farmers, WFI is preferred above crop-specific revenue insurance.

Results also indicate that the impacts on crop allocations of income risks are of rather lesser importance. Three major reasons for this can be indicated: first, direct payments make up a large percentage of the agricultural income of crop farms in the Netherlands, which makes them less vulnerable to income fluctuations. Second, arable crop farms have to cultivate at least three different crops to meet cross-compliance requirements. Third, even without insurance, farmers will choose to plant onions and potatoes over the other crops because of their larger gross revenues. Therefore, only with higher levels of eligibility, crop insurance becomes interesting to farmers.

WFI is considered to fall into the WTO's 'green box', meaning that the presence of WFI should not affect crop allocation decisions. However, we find that the possibility of WFI leads to very different effects per crop, with generally more land allocation towards more volatile crops potatoes and onions and away from more stable crops such as cereals. The possibility of WFI leads also to very different effects per farm type. Relatively larger changes are observed for smaller farms under WFI, meaning that the insurance and wealth effects of these farms are larger. On the one hand, because all crops are targeted equally, whole farm programs are seemingly decoupled. The fact that different types of farms, who are likely to have different degrees of risk aversion, react to different degrees, supports this argument. However, the general optimization towards more volatile crops might give indication of coupling, which is of course against WTO decisions. This provides indication of an insurance effect when farmers are offered whole farm income insurance, providing an effective lower bound on a producer's income.

The effect is not as large as often expected though. Farmers are constraint not only by their own aversion to risk, but also by production constraints such as crop rotation. Moreover, under the 2013 CAP reforms, it was decided that farmers had to meet green practices in order to be entitled to part of the single farm payments they receive. These requirements include the cultivation of multiple crops, likely further reducing the possibility for farmers to enter monoculture (European Commission, 2014c). This, together with the fact that only losses above 30% will receive compensation under WFI, still leads to quite some diversification in farm plans.

There are some caveats to the research. First, we only looked at the impact that risk management programs have on land use, ignoring other inputs into agricultural production. While both risk management and environmental policy are specifically regulated as part of the European Union's agricultural policy, it is not yet clear how the two might act together, and whether they offset each other. For example, at least one study has shown that subsidizing insurance could offset the environmental benefits created by direct payment policies (Capitanio *et al.*, 2015). Relatedly, we assumed that the total area of cropland available to a farmer was fixed, but Capitanio *et al.* (2015) argue that risk management programs could induce farmers to bring marginal land into production. However, in a country where land is as scarce as in the Netherlands, this will unlikely be the case. Second, whether farmers respond to changes in the EU's farm policies also depends on farmers' utility functions, with some farmers unlikely to modify their cropping decisions while others will change the way they allocate land among crops. In this study we did not account for possible differences in utility functions.

CHAPTER 7. SYNTHESIS

This final chapter draws general inferences from the topics discussed in chapters 2-6. The first section addresses a selection of theoretical issues in analysing land use change, and reflects on the data and models employed in this thesis. The second section provides the main conclusions of this thesis.

7.1 Discussion

In this section three central issues are discussed. The first are the theoretical choices with respect to the elements of the Common Agricultural Policy (CAP) reform, risk and uncertainty and agricultural land use (change) outlined in the introduction of this thesis. The second issue deals with the data employed and their subsequent advantages and disadvantages. The third issue deals with the mathematical programming and econometric models chosen to answer the specific research questions.

7.1.1 Theory

CAP reform

This thesis aims to make statements on the introduction, change or abolition of specific policy measures in the light of the CAP reforms. The influence of direct payments is discussed in Chapters 2 and 5, milk quota abolition is discussed in Chapter 3 and insurance is the subject of Chapter 6. The CAP is not the only policy that influences farmers' decision-making. Spatial policies, as explained in the introduction, restrict the location and type of land use in a certain area by means of zoning. They are therefore of large importance to the amount and location of agricultural land. This thesis aims at analysing land use changes within the agricultural sector, and does not focus on changes to the total amount of agricultural land. The CAP reform

is therefore seen as the main driver of land use changes within agriculture, while recognizing that other policies such as the Nitrate Directive are of importance as well. Quantifying the effects of a policy change by analysing farmers' behaviour is relatively straightforward when there is only one policy change. Most studies analysing CAP reform have tried to single out specific policy measures. The CAP is however comprised of a range of policy measures that are often simultaneously enforced, complicating the analysis. Moreover, the effect of specific policy measures differs in importance between farm types and sectors. For example, for dairy farmers, milk quotas are replaced by Single-Farm Payments, making it difficult to quantify their separate effects on land use change. Some studies have therefore aimed at a more comprehensive assessment of CAP reform policies (Piorr *et al.*, 2009; Sckokai and Moro, 2006).

Risk and uncertainty

Producers are assumed to be rational agents who optimise an objective function. This may for instance be maximizing profit or maximizing utility by accounting for risk in farmers' decision-making (Chavas and Pope, 1985; Coyle, 1999). Both under the profit-maximizing and utility-maximizing framework, shadow prices of land can be derived. In Chapters 2, 5 and 6 the shadow price of land depends on the risk perceived by farmers.

Chapter 2 develops a conceptual framework where risk is incorporated in the utility-maximising behaviour of farmers. As an indicator of risk the historic variation of expected output prices has been used. However, for an individual producer, increased output price volatility does not necessarily imply changes in the level and variance of income, since a producer's income is also dependent on input costs and yields, and the correlation between prices and yields (Pennings, 2010). Where some existing studies have only focused on price uncertainty (Femenia *et al.*, 2010), others have includes price and yield uncertainty (Bakhshi and Gray 2001; Lehmann *et al.*, 2013; Moro and Sckokai, 2013) or even accounted for policy uncertainty (Bhaskar and Beghin, 2010). The conceptual framework of Chapter 2 is therefore

extended in Chapters 5 and 6 by not only considering price volatility but also yield volatility and the total variation in revenues. Monte Carlo simulations of historic output prices and yields, multiplied by an Arrow-Pratt risk coefficient have been used to measure risk.

The utility functions formulated in Chapters 2, 5 and 6 are somewhat simplified. Decisions on land-use change do not depend on utility as a function of income and risk alone, but may also incorporate speculation (Power and Turvey, 2010), farm characteristics (Weiss 1999; Gale, 2003; Breustedt and Glauben, 2007) as well as farm location (Livanis *et al.*, 2006). This may lead to farmers specifying alternative objectives such as production growth or farm survival (Weiss, 1999; Foltz, 2004). Besides alternative objectives of farmers, different driving factors might interact with each other. Driving factors are often subdivided into socio-economic, biophysical and land-management drivers (Lambin *et al.*, 2001).

Agricultural land use change

Changes to the use of land do not instantaneously take place when shadow prices change; a farmer may be concerned with adaptation costs related to land use change. The size of such costs is largely dependent on whether the total amount of land available on the farm is considered fixed or variable. Chapters 2, 5 and 6 analyse land use changes given that the total amount of land is fixed. Here, land use change may be influenced by short-term expectations on profitability and perceived risk only. Chapters 3 and 4 account for changes to the total amount, and therefore use, of land on a farm. Changes to the total amount of land are necessarily influenced by long-term expectations also, and therefore include adaptation costs. Chapters 3 and 4 attempt to analyse and quantify factors besides those directly coming from changes to shadow prices, such as farm characteristics (Chapter 3), location and institutional factors (Chapter 4).

A consistent theoretical framework to support this differentiation both analytically and empirically has not been developed. The lack of such a framework incorporating both

economic and non-economic factors stems from the complexity of long-term changes, especially when land transactions are involved. Approaches that do consider long-term perspectives of farmer's decision-making include the application of real-option theory (Dixit and Pindyck, 1994). Such approaches focus on the optimal timing of change, but do not differentiate between different kind of changes.

7.1.2 *Data*

This thesis employs three different datasets that describe factors relating to land use change: the Farm Structure Survey (FSS), Farm Accountancy Data Network (FADN) and the national land transaction database (LEI, 2014e; Statistics Netherlands, 2014). Chapters 2 and 3 focus on the FSS data, Chapter 4 employs all three datasets, and Chapters 5 and 6 use the FADN. Using these different datasets allows analysis at different scales (regions, farms, hectares of land). Where the FADN contains a sample of farms with a lot of information, the FSS contains the complete population of farms with a limited amount of information. Quantifying the influence of different driving forces on both the magnitude and the dynamics of land use change depends on the scale at which it is studied. The unit of analysis of this thesis has been individual farms mostly, yielding socio-economic factors as important explanatory variables for land-use change. However, there is evidence that driving factors play different roles at different scales. Where socio-economic factors are important at micro-level, climatic, macro-economic and demographic factors may be more important at a regional and at macro-level (Veldkamp and Lambin, 2001). Extrapolating the behaviour of farmers to a more aggregate level therefore has to be done with caution.

Two other issues related to the data persist. First, where data was missing, proxies coming from higher aggregation levels were used; possibly leading to errors. Some variables, such as the introduction or abolition of specific policies, are difficult to quantify and dummies or trends had to be used. This requires cautious interpretation because such trends may also

capture other developments. Second, historical data cannot analyse changing or new policies because the data does not entail variations due to changes in such policies. Farm structural change can therefore only be analysed after it has been observed in the data.

7.1.3 *Models*

Models analysing land-use change that employ a coherent decision-making framework improve the analysis of causes and consequences of land-use change. However, driving forces are spatially and temporally interrelated, complicating the ability of such models to achieve a comprehensive understanding of land-use change. Studies on land use therefore require knowledge of multiple methods. Depending on the research question, the theoretical framework and available data, the most appropriate method was chosen. Where historic data was available and the aim was to analyse changes over time, we used (panel data) econometric approaches. Where historic data was scarce and the aim was to analyse potential effects of reforms not yet implemented, we used mathematical programming. Chapters 2, 3 and 4 use various forms of (panel data) econometrics, Chapters 5 and 6 use mathematical programming models. This section discusses the advantages and disadvantages of both.

Econometric models

Econometric models have been used in Chapters 2, 3 and 4. With respect to Chapter 2, three methodological issues persist. First, the complexity of the optimisation problem and availability of input-output data on farm level does not allow for a full estimation of the utility-maximizing framework developed. This leads to the adoption of a reduced-form approach. Although theoretically not very satisfying, reduced-form approaches allow for the inclusion of other variables besides those related to the generation of income, such as policy, socio-economic and wider economic-political variables. Second, when using panel data econometrics, specific effects of the observation unit are of importance. In Chapter 2, these are

region-specific effects. A fixed-effects model that allows for the inclusion of such unit-specific effects is therefore used, resulting in an improved explanation of the variance between regions. Interpretation of the region-specific effects may however be difficult. Variations between farms could for instance be due to differences in soil, management and production intensity. Finally, the fixed-effects panel data model estimated in Chapter 2 deals with agricultural land use change as a stationary process which may not be true in reality.

To overcome the stationary element and to focus on the dynamics, Chapter 3 uses a duration model to explain land use change. Duration models are a special form of panel data econometrics that analyses the impact of factors influencing the length of time between two changes in land use (see e.g. Cleves *et al.*, 2008). A parametric duration model is used in order to deal with the specific features of our data: time-varying explanatory variables, delayed entry, time gaps, and right censoring. However, this approach also has its caveats. First, where Chapter 2 is only able to explain the magnitude and not the dynamics of change, Chapter 3 is only able to explain the dynamics and not the magnitude of change. Testing for different magnitudes of land use changes does however show that results are quite robust. Second, the impossibility of including magnitudes of change and multiple equations implies that it is not possible to give a complete explanation of farm structural change using a duration model.

Chapters 2 and 3 ignore the influence of location in analysing changes, even though agriculture is land-based and thus spatially explicit. Space may be taken into account by location-specific, autoregressive or spatial error variables (Anselin, 1988; LeSage and Pace, 2009). Chapter 4 includes location-specific variables and tests for a spatial lag and spatial error model. Integrating land use changes through both time and space could be a valuable exercise and may help to provide more insight in the effects of policy changes, such as the changes to the CAP or to spatial policies. Chapter 4 provides a first attempt to do so.

Mathematical programming models

The revised Single-Farm Payments (SFP), as described in the 2013 CAP reforms, are yet to be implemented. The possibility of whole-farm income (WFI) and crop-specific insurance is a hypothetical policy instrument. For both measures it is therefore not possible to use historic data to analyse their effects. Chapters 2, 3 and 4 considered land-use changes through time, and therefore used econometric models. Chapters 5 and 6 analyse future and hypothetical changes and for that purpose require mathematical programming models.

When using such models, optimal land allocation plans can be established for farms using a minimal amount of data. Moreover, these models are able to deal with shifts in farm behaviour when triggered by socio-economic events such as a policy change. The possibility of corner solutions, where a farmer is unable to make trade-offs, is however a potential drawback of these models, leading to extreme outcomes when a threshold is passed. In Chapters 5 and 6 this is circumvented by using positive mathematical programming (PMP) (Howitt, 1995). An average-cost approach is employed to calibrate the model such that it precisely duplicates the observed allocation of land to crops. Unfortunately, a unique or best PMP method does not exist, especially when the objective function differs from maximizing gross revenues. Another disadvantage of the mathematical programming models used in this thesis is that they have been applied to only a few farms of different sizes due to a lack of data and resources. This makes it difficult to draw general conclusions on the imposed policy measures for the farming sector. Moreover, mathematical programming models are comparative static models. Dynamic programming, taking into account both the magnitude and pace of land use changes could therefore be a possible alternative for the models used. The foundations for dynamic programming have been laid out by Bellman (1957). More recent examples of dynamic agricultural land-use modelling include Thornton and Jones (1998), Stephenne and Lambin (2001), Mary (2013) and Briner *et al.*, (2012). However, such models require more data and assumptions on (dynamic) behaviour.

7.2 Summary of main conclusions

Five driving factors that potentially influence land use changes are defined in the introduction and subsequently analysed in Chapters 2 through 6. In this section the main conclusions are summarised and implications for land use changes in the Netherlands are given. An overall conclusion on the general objective concludes this section.

Volatile output prices

The European Union's CAP is shifting away from market and price support to liberalized markets and payments decoupled from production. Chapter 2 assesses the effect of resulting volatile agricultural output prices, and hence farm profits, on farmer's land use decision-making since 2000 in the Netherlands. More specifically, by estimating a system of land-response equations, accounting for the effects of price uncertainty on its own and alternative land uses, the effect of output price volatility is investigated. Two main conclusions can be drawn. First, the results show that relative price variation matters and serves as a proxy for the degree of perceived risk. Second, changes between land uses depend on whether production activities are complements or substitutes. For dairy farming, fodder maize and grassland appear to be complements. For arable farming, cereals, sugar beets, and potatoes appear to be complements, whereas onions and grassland appear to be substitutes. This indicates that a producer may view alternative production decisions only within the context of either arable or dairy farming, depending on his current production activities. This could be due to adaptation costs related to shifts between arable and dairy farming.

Milk quota

Adaptation costs may be related to policy (in our case milk quota), socio-economic, farm income and economic-political variables. Depending on the level of adaptation costs the shadow price of land can vary within a certain range before an actual land use change takes

place, impeding land dynamics. The purpose of Chapter 3 is to analyse the time period between two changes in land used for milk production on dairy farms and the direction of land use change over a period before, during and towards the abolition of milk quota. Employing a duration model and using farm-level data from the Netherlands between 1971 and 2011, the pace of changes in agricultural land use is analysed. Results show that quotas hamper the pace of change for expansion in land used for milk production. Therefore, quota abolition will lead to a more dynamic dairy sector. Furthermore, the pace of land use changes is highly farm-specific; younger farm operators with a higher education level, who do not work full-time on the farm, and farmers who have a successor and do not yet dedicate a large portion of their total land to milk production exhibit highest dynamics in land use change in favour of milk production. In contrast, farmers with a low education level and without a successor exhibit highest dynamics in land use change away from milk production.

Land prices

Farm-specific effects are further explored in Chapter 4, where the objective is to explain farmland prices in the Netherlands, and more specifically the effect of the financial crisis on the agricultural land market in the Netherlands between 2004 and 2011. Prices of farmland are usually derived by taking the net present value (NPV, i.e. discounting) of the future stream of income generated from the land (Ahearn *et al.*, 1997, Latruffe and Le Mouël, 2009, Roberts and Key, 2008, Weersink, *et al.*, 1999). However, the price of farmland cannot be explained as an income-generating asset alone. In Chapter 4, four categories influencing the price of land are distinguished: (i) the direct influence via the returns from land, (ii) institutional regulations, (iii) the spatial environment and (iv) local market conditions. Furthermore, two periods are compared to distinguish the effect of the crisis on the agricultural land market. Results indicate that all categories significantly influence land prices. Moreover, the financial crisis leads to a decline in the effects of local market conditions, whereas the announcement

of milk quota abolition in 2008 has led to an increase in the effects of the spatial environment between the first and the second period. The results of Chapter 4 therefore highlight the need to look beyond discounted agricultural shadow prices of land in determining the effects of farm-land prices.

Chapters 5 and 6 develop mathematical programming models that maximize utility of representative farmers of different sizes by selecting various land use allocations. The influence of respectively SFP and insurance on farmer's land allocation decisions is analysed. Neither the SFP nor insurance should affect a producer's land-use decisions because they are both listed as 'green box' items in WTO regulations.

Direct payments

The EU's December 2013 agreement on CAP reforms stated that direct payments adopted in the Mid-Term Review would be abolished by 2015 and replaced with a flat-rate payment per hectare regardless of what crops are planted. In addition, landowners will be compensated for environment-friendly farming practices, the so-called greening component. The objective of Chapter 5 is to analyse the potential impact of the move to SFP with a greening component on producers' land-use decisions. Results indicate that the 2013 CAP reforms will cause farmers to shift away from crops previously eligible for payments, with the initial shift under the SFP enhanced by the move towards SFP combined with green payment. Moreover, the change from a historic to a flat-rate payment affects the shadow price of land for some types of farmers more than others, which in turn leads to differences in changes to land use between farms. This is largely dependent on the degree of risk aversion of the farm, with more risk-averse farmers unlikely to modify their cropping decisions and less risk-averse ones more willing to reallocate land among crops. With respect to the greening component of the reform in direct payments, diversification measures do not influence farmer's crop allocation

decisions because of crop rotation schemes, but environmental set-aside requirements substantially alter farm income and cropping plans.

Insurance

Chapter 6 analyses the impact of Whole Farm Income (WFI) and crop-specific insurance on producer's crop allocation decisions. Using data of Dutch arable producers of different sizes, optimal crop portfolio was investigated, where insurance depends on farmer's crop allocation, while at the same time that allocation depends on the type of insurance provided. Results indicate that, by taking away part of the revenue volatility, insurance schemes alter farmer's land allocation plans towards a larger share of crops with a higher volatility. More specifically, this means a decrease in area allocated to wheat and barley, and an increase in area allocated to potatoes and onions. Smaller farms observe relatively larger changes in WFI, whereas larger farms observe relatively larger changes with crop-specific insurance. Land-use changes are larger with crop-specific than with whole farm insurance, with the latter biased towards smaller farms. Results are however highly dependent on the level of risk aversion. For both SFP and WFI changes to crop allocation are small, and even smaller under direct payments compared with insurance. However, the small but notable optimization towards more volatile crops under both SFP and WFI may indicate that even decoupled farm payments do subsidize production, contrary to WTO regulations.

7.3 General conclusion

The general objective of this thesis is to investigate farmers' decision-making on agricultural land-use changes in the Netherlands, accounting for the role of the EU's CAP reform. Different effects, potentially affecting production decisions, may result from government support measures. These can be grouped into coupling effects, linking support to production; wealth effects, increasing producer's income; and insurance effects, decreasing a producer's income

variability (Hennessy, 1998). All these effects are likely to influence producer's aversion to risk. However, risk aversion is inherently coupled to the farmer himself; when production risk is decreased, this opens the possibility to increase risk in other areas, such as farm expansion. The coupling effect of government support is reduced, but not eliminated, by the decoupling of the CAP reforms. The resulting increased price volatility leads to negligible land use changes. Direct payments only entail a wealth effect, leading to very small, but significant changes to crop allocation away from crops that used to receive subsidies. Insurance schemes entail both a wealth and an insurance effect, leading to somewhat larger, but still small changes to crop allocation towards more volatile crops. The effects of increased price volatility, reforms in the direct payment system and hypothetical insurance schemes analysed in Chapters 2, 5 and 6 all lead to small but notable changes to agricultural land use due to changes in farmers' perceived risk. The small changes observed in these chapters are partly due to the fact that the total size of the farm is treated as fixed. Moreover, changes are likely to take place within a certain production system (e.g. arable or dairy farming). Land allocation is to a large extent imposed in the current production system due to, for instance, crop rotation and nitrate regulations.

Farmer's decision-making on agricultural land-use changes may also involve buying (leasing) or selling (renting out) land. Chapters 3 and 4 treat the total amount of farmland as variable. This causes adaptation costs to be of importance; implying that changes to land cannot be explained by changes to the shadow price of land alone. Here, larger effects of driving forces on land use change are found. Land use changes given a fixed farm size are mostly influenced by short-term decision making based on changes in farm profitability and perceived risk. Land use changes in case farm size can alter are also influenced by long-term decision-making based on expectations on future costs and revenues, and other factors such as farm characteristics, institutional and transaction characteristics and the influence of location. Decision-making on agricultural land-use changes therefore depends on the time horizon of

the use of the land. This shows that land-use change is complex and caused by different factors that interact with each other, leading farmers to base their land use decisions on more than changes to the shadow price of land alone.

Due to this complexity, different research methods and data are needed to capture and analyse different elements of farmers' decision-making on land-use change. This thesis addresses several issues, and consequently applies a variety of methods and uses different data. Results of this thesis can be used especially to assess the influence of current and future CAP reforms, but also to gain a deeper insight into (the dynamics of) land use changes in the Netherlands.

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SUMMARY

Farmer's decision making on agricultural land use change is often explained by combining the effects of relative profitability, risk aversion, price uncertainty, and yield uncertainty on production decisions. However, there is only so much room for change due to the opportunities and restrictions that two protective policies, zoning and the Common Agricultural Policy (CAP), impose. To a certain extent, these two policies lay the foundations for agricultural land use and its competition with non-agricultural land. With changes to these policies, a reallocation of land can therefore also be expected. At the changing interplay between the CAP and spatial policies this dissertation aims to investigate driving forces of agricultural land use change in the Netherlands.

The general objective of this study is to investigate farmers' decision-making on agricultural land use changes in the Netherlands, accounting for the role of the EU's CAP reform. The Netherlands provides a relevant context to address this objective due to the co-existence of strict zoning policies and the degree to which farmers are affected by changes to the CAP reform. The country is densely populated, making land scarce, and competition for land exists both within the agricultural sector and between agriculture and other sectors. Besides, the availability of large-scale temporal and spatial datasets allows us to analyse land use changes both through time and space. From the general objective, the following five driving factors that potentially influence land use changes are defined and analysed in separate chapters. 1) To investigate the effect of volatility in agricultural output prices on agricultural land use. 2) To analyse the effect of the abolition on milk quota on the pace of agricultural land-use change. 3) To explain farmland prices, and more specifically the effect of the financial crisis on the land market. 4) To investigate the effect that different direct payment mechanisms have on land use (crop allocation) decisions. 5) To analyse the effect of crop-specific and whole farm income insurance on agricultural land use change.

By establishing a system of land-response equations, Chapter 2 assesses the first objective of the study. The effect of producer-price volatility, and hence farm profits, on farmers' land use decision-making since 2000 in the Netherlands is investigated. By accounting for the effects of price uncertainty on existing and alternative land uses, the effect of output price volatility is analysed. Results show that relative price variation matters and serves as a proxy for the degree of perceived risk. Within these relative price variations, it matters whether production activities are complements or substitutes. For dairy farming, fodder maize and grassland appear to be complements. For arable farming, cereals, sugar beets, and potatoes appear to be complements, whereas onions and grassland appear to be substitutes. A farmer therefore views alternative land uses mostly within the context of either arable or dairy farming, depending on his current production activities. This could be due to additional costs related to shifts between production systems; in this study referred to as adaptation costs.

Adaptation costs do not only occur with shifts between production systems, but may also occur with changes in farm size. These costs may be related to policy (in our case milk quota), socio-economic, farm income and economic-political variables. To address the second objective, Chapter 3 analyses whether quota abolition will lead to a more dynamic dairy sector. Using a unique dataset comprising farm-level data from the Netherlands between 1971 and 2011, the pace of changes in agricultural land use is analysed. Employing a duration model, we find that quotas hamper the pace of change for expansion in land used for milk production. The pace of land use changes is highly farm-specific; younger farm operators with a higher education level, who do not work full-time on the farm, and farmers who have a successor and do not yet dedicate a large portion of their total land to milk production exhibit the highest dynamics in land use change in favour of milk production. In contrast, farmers with a low education level and without a successor exhibit the highest dynamics in land use change away from milk production. Adaptation costs are therefore found to be higher for this latter group of farmers, impeding land dynamics.

Using data on around 20,000 agricultural land transactions over the period of 2004-2011, farmland prices are explained with the objective to analyse the effect of the financial crisis on the land market price, controlling for other factors explaining farm land prices. Four categories that potentially influence land prices are analysed: (i) the direct influence via the returns from land, (ii) institutional regulations, (iii) the spatial environment and (iv) local market conditions. While correcting for spatial lag in the data, two periods are compared to distinguish the effect of the crisis on the agricultural land market. The expected net revenue obtained from farming explains only part of the price of farm land. Farm type, farm characteristics, institutional and transaction regulations, seasonal fluctuations and location all have their effect on the price of land. While the difference between the two periods analysed is generally small, there is some indication that after the onset of the financial crisis, the local market conditions that determine the option value of land have become less important. On the contrary, the spatial environment has become more important due to the announcement of milk quota abolition in 2008.

In order to explain the last two objectives, the influence of farm subsidy reform and the possibility of insurance mechanisms, mathematical programming models are developed that maximize the utility of representative farmers of different sizes by selecting various land use allocations. In both models, a two-step calibration method is used to determine a nonlinear cost function and farm-specific risk aversion coefficients. The impact of the move to fixed per-hectare payments (SFP) with a greening component shows both a farm- and a crop-specific effect. The 2013 CAP reforms will cause farmers to shift away from crops previously eligible for payments, with the shift under the SFP enhanced by the move towards SFP combined with a greening payment. In the insurance model, insurance depends on a farmer's crop allocation, while at the same time crop allocation depends on the type of insurance provided. Results indicate that, by taking away part of the revenue volatility, whole farm insurance (WFI) alters farmers' land allocation plans towards a larger share of crops with a higher volatility. Both

models therefore show a relatively larger use of the most profitable crops (often potatoes in arable farming), reducing the amount of land devoted to cereals (wheat and barley combined). Smaller farms show relatively larger changes, meaning that the insurance and wealth effects of these farms are larger. However, changes in land allocation are not as large as sometimes expected, due to, among others, crop rotation requirements. The small but notable optimization towards more volatile crops under both SFP, WFI and crop-specific revenue insurance indicates that even decoupled farm payments do subsidize production, contrary to WTO regulations.

The last chapter of this dissertation (Chapter 7) provides the main conclusions and a discussion of the research and provides further insight in why land use change does or does not take place with changes in the environment in which farmers operate. Risk aversion is inherently linked to the farmer himself; when production risk is decreased, this opens the possibility to increase risk in other areas, such as farm expansion. The effects of increased price volatility, reforms in the direct payment system and hypothetical insurance schemes analysed in the first, fourth and fifth objective all lead to small but notable changes to agricultural land use due to changes in the farmer's perceived risk. The small changes observed in these chapters are partly due to the fact that the total size of the farm is treated as fixed and the fact that land allocation is to a large extent imposed in the current production system due to, for instance, crop rotation and nitrate regulations. When the total amount of farmland is treated as variable, such as in the second and third objective, changes to land cannot be explained by changes to the shadow price of land and risk alone. Land use change is now also influenced by long-term decision-making based on expectations on future costs and revenues, and other factors such as farm characteristics, institutional and transaction characteristics and the influence of location and economic conjecture. This shows that land-use change is complex and caused by different factors that interact with each other, leading

farmers to base their land use decisions on more than changes to the shadow price of land alone.

SAMENVATTING

De besluitvorming van boeren over landgebruik wordt vaak uitgelegd aan de hand van de invloed van relatieve winstgevendheid, risico-aversie, onzekerheid over prijzen en opbrengsten op veranderingen in productiebeslissingen. De ruimte voor verandering is echter beperkt door de mogelijkheden en beperkingen opgelegd door twee soorten beleid: ruimtelijke ordening en het gemeenschappelijk landbouwbeleid (GLB). Tot op zekere hoogte vormen ruimtelijke ordening en het GLB de basis voor de indeling van agrarisch land en de concurrentie met niet-agrarische vormen van landgebruik. Veranderingen in het beleid kunnen daardoor een verandering in landgebruik veroorzaken. Het hoofddoel van dit proefschrift is om in tijden van een veranderende wisselwerking tussen het GLB en ruimtelijk beleid de drijvende krachten achter landgebruiksveranderingen in de agrarische sector in Nederland te onderzoeken.

De doelstelling van dit proefschrift is het nagaan van de besluitvorming van boeren over veranderingen in agrarisch grondgebruik in Nederland, rekening houdend met de veranderingen in het GLB. Nederland vormt een relevante context voor dit doel door het samengaan van een strikt ruimtelijk orderingsbeleid en de mate waarin boeren beïnvloed worden door veranderingen in het GLB. Nederland is dichtbevolkt, waardoor land schaars is, en de concurrentie voor land zowel binnen de landbouwsector als tussen de landbouw en andere sectoren bestaat. Verder bestaan er grote datasets met zowel een tijd- als ruimtelijke dimensie. Uit het hoofddoel van dit proefschrift zijn de volgende vijf drijvende factoren van landgebruiksverandering geselecteerd om te worden behandeld als subdoelen in afzonderlijke hoofdstukken: 1) Het effect van schommelingen in agrarische output prijzen op agrarisch landgebruik. 2) Het effect van de afschaffing van melkquota op de snelheid van veranderingen in agrarisch landgebruik. 3) Het analyseren van prijzen van agrarisch grond, en meer specifiek het effect van de financiële crisis op de grondmarkt. 4) Het effect dat directe

betalingen hebben op beslissingen over land gebruik. 5) Het effect van gewas specifieke- en inkomensverzekeringen op agrarisch grondgebruik.

Het eerste subdoel van dit proefschrift wordt behandeld in hoofdstuk 2 waar een systeem van vergelijkingen de reactie op landgebruik analyseert. De invloed van volatiliteit in de producentenprijs, en daarmee winst, op de landgebruiksbeslissingen van boeren in Nederland sinds 2000 is onderzocht. Door rekening te houden met de effecten van prijsonzekerheid op bestaande en alternatieve vormen van gebruik, wordt het effect van schommelingen in de producentenprijs geanalyseerd. Resultaten laten zien dat de relatieve prijsvariatie van belang is en dient als een maatstaf voor door de boer waargenomen risico. Binnen deze relatieve prijsvariabiliteit is het van belang of productieactiviteiten complementen of substituten zijn. Voor melkveehouderij zijn ruwvoer en grasland complementen. Voor akkerbouw zijn granen, suikerbieten en aardappelen complementen, en uien en grasland substituten. Een boer ziet daarom zijn alternatieve vormen van landgebruik meestal binnen de context van akkerbouw of melkveehouderij, afhankelijk van zijn huidige productieactiviteit. Dit kan veroorzaakt worden door extra kosten gerelateerd aan een overgang tussen productie systemen; waar hierna verwezen wordt als 'adaptatiekosten'.

Adaptatiekosten komen niet alleen voor bij een overgang naar een ander productiesysteem, maar kunnen ook voorkomen bij veranderingen in de grootte van de boerderij. Deze kosten kunnen gerelateerd zijn aan beleid (in dit geval melkquota), socio-economische, inkomens of economisch-politieke variabelen. Hoofdstuk 3 analyseert het tweede subdoel; in welke mate de afschaffing van het melkquota leidt tot een meer dynamische melkveesector. Gebruik makend van een unieke dataset met gegevens op bedrijfsniveau tussen 1971 en 2011 in Nederland wordt de snelheid van veranderingen in agrarisch grondgebruik geanalyseerd. Analyse met een *duration model* toont aan dat de snelheid van uitbreiding van land voor melkproductie wordt belemmerd door het quotabeleid. De snelheid van veranderingen is bovendien erg bedrijfsspecifiek, waarbij jongere boeren met een hoger scholingsniveau, die

niet fulltime op het bedrijf werken, waarvan de bedrijfsleider een opvolger heeft en nog geen groot deel van het bedrijf aan melkproductie besteden meer dynamiek richting uitbreiding van melkproductie ervaren. Bedrijven met een lager scholingsniveau en zonder een opvolger ervaren daarentegen een versnelling in landgebruiksveranderingen richting een lager niveau van melkproductie. Adaptatiekosten kunnen daarom hoger zijn voor deze laatste groep, wat de dynamiek van landgebruiksveranderingen belemmerd.

Met behulp van 20.000 transacties van agrarisch land over de periode van 2004 tot 2011 worden prijzen van agrarisch land geanalyseerd met het doel om het effect van de financiële crisis op de prijs van de landmarkt te analyseren, rekening houdend met andere factoren die landprijzen beïnvloeden. Vier categorieën die mogelijk landprijzen beïnvloeden worden geanalyseerd: 1) de directe invloed van de opbrengst van agrarisch land; 2) institutionele factoren; 3) het ruimtelijke milieu; 4) lokale marktcondities. Door te corrigeren voor effecten van *spatial lag* worden twee periodes met elkaar vergeleken om de invloed van de crisis op de agrarische grondmarkt te analyseren. De verwachte netto opbrengst gehaald uit agrarische productie bepaalt slechts een deel van de prijs van agrarisch land. De sector, karakteristieken van het bedrijf, institutionele en transactiereguleraties, seizoensfluctuaties en de ligging bepalen mede de prijs van agrarisch land. Ondanks het kleine verschil in de periode voor en na de financiële crisis, vinden we enige indicatie dat na de start van de crisis de lokale marktcondities die de optie waarde van land bepalen in belang verminderen. De ruimtelijke omgeving is daarentegen steeds belangrijker geworden vanwege de aankondiging in 2008 om melkquota af te schaffen.

De laatste twee subdoelen, de invloed van de hervormingen van de directe betalingen en de mogelijkheid van verzekeringen worden geanalyseerd met behulp van mathematisch programmeringsmodellen die het nut van representatieve boeren analyseren door het optimaliseren van het landgebruik. In beide modellen wordt gebruik gemaakt van een kalibratiemethode die zowel de niet-lineaire kostenfunctie als de bedrijfsspecifieke risico-

aversie coëfficiënt herleidt. De invloed van de hervorming in de directe betalingen met vergroeningscomponent laat zowel een bedrijfs- als een gewasspecifiek effect zien. De 2013-hervormingen van het GLB zorgen ervoor dat de gewaskeuze van boeren wegschuift van gewassen die voorheen vereist waren voor het verkrijgen van subsidies. De mate van verschuiving wordt groter wanneer er ook rekening wordt gehouden met vergroeningsmaatregelen. In het verzekeringsmodel hangen verzekeringen af van de gewaskeuze, terwijl de gewaskeuze tegelijkertijd afhangt van het type verzekering. Door een deel van de volatiliteit in opbrengst weg te halen beïnvloeden inkomensverzekeringen de besluitvorming over landgebruik van een boer richting het planten een groter aandeel van gewassen met een hogere volatiliteit. Beide modellen geven daarom een relatief groter aandeel van land voor meer winstgevende gewassen (vaak aardappelen in akkerbouw) en verminderen het aandeel land voor granen (tarwe en gerst samen). Kleinere boeren laten relatief grotere veranderingen zien, door onder meer vereisten aan gewasrotaties. De kleine, maar zichtbare, optimalisatie richting gewassen met grotere schommelingen in opbrengst onder zowel GLB hervormingen als mogelijkheden om (een deel van) het inkomen te verzekeren geven aan dat zelfs volledig ontkoppelde steun een invloed heeft op productie; tegengesteld aan de regelgeving van de WTO.

Het laatste hoofdstuk van dit proefschrift (hoofdstuk 7) geeft de belangrijkste conclusies en een discussie van het onderzoek en biedt meer inzicht in waarom landgebruiksveranderingen wel of niet plaatsvinden met veranderingen in het milieu waarin de boer opereert. Risicoaversie is inherent aan de boer; wanneer risico in productie vermindert kan risico in andere gebieden worden vergroot, zoals in de uitbreiding van de boerderij. De effecten van toegenomen prijsvolatiliteit, hervormingen in de directe betalingen en de mogelijkheden om (een deel van) het inkomen te verzekeren die geanalyseerd zijn in het eerste, vierde en vijfde subdoel leiden allen tot kleine, maar aanwezige, veranderingen in landgebruik veroorzaakt door veranderingen in risico waargenomen door de boer. Dat de waargenomen

veranderingen in deze hoofdstukken klein zijn, wordt deels veroorzaakt door het feit dat de grootte van het bedrijf vast staat en dat de indeling van land in grootte mate afhangt van het huidige productiesysteem vanwege, bijvoorbeeld, gewas rotatie en nitraat wetgeving. Als de totale hoeveelheid land wordt behandeld als variabel, zoals in het tweede en derde subdoel, kunnen veranderingen in land niet alleen worden uitgelegd aan de hand van veranderingen in de marginale opbrengst van land en waargenomen risico alleen. Landgebruiksveranderingen worden nu ook beïnvloedt door lange-termijn besluitvorming gebaseerd op verwachtingen over toekomstige kosten en opbrengsten, en andere factoren zoals karakteristieken van de boer, institutionele en transactie karakteristieken en de invloed van de ligging van het land en de economische conjunctuur. Dit laat zien dat landgebruiksverandering complex is en wordt veroorzaakt door verschillende factoren die met elkaar interacteren, wat leidt tot boeren die hun beslissingen maken op meer dan alleen de marginale opbrengst van land.

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Esther Boere
May, 2015.

BIOGRAPHY

Esther Boere was born on April 25, 1987 in Oosterhout. She finished her secondary school in 2005, after which she began to study International Development Studies in Wageningen. In 2010 she completed a master's degree in Development Economics. Part of her master thesis was a 6 month stay in the Northern mountainous areas of Vietnam where she designed alternative Payment for Ecosystem Services (PES)-programs, resulting in a publication in *Land Use Policy*.

In December 2010, Esther started as a PhD candidate at both the Agricultural Economics and Rural Policy Group (AEP) and the Agricultural Economic Research Institute (LEI). During her PhD she spent a summer at the University of Victoria, Canada to work on modelling insurance possibilities in the Netherlands. As part of her PhD research, she has presented papers at various scientific conferences (e.g. EAAE) and followed various courses given by both the Wageningen School of Social Sciences (WASS) and the Netherlands Network of Economics (NAKE). In addition, she assisted with courses and the supervision of master students at the AEP group.

Esther joined the International Institute of Applied System Analysis (IIASA) as a Research Scholar in January 2015. She currently works at the Ecosystems Services and Management (ESM) Program on land use analysis. Her current scientific interests include the analysis and modelling of driving factors of (agricultural) land use change.

Name of the learning activity	Department/Institute	Year	ECTS*
A) Project related competences			
Writing research proposal	WUR	2010-2011	4
Agricultural and Rural Policy Analysis (AEP 30306)	WUR	2011	6
Spatial Econometrics, theory and practice	WASS	2011	1.5
Advanced microeconomics (ECH 32306)	WUR	2011	6
Microeconomic panel data	NAKE, Utrecht	2011	3
Econometric and mathematical programming models for policy analysis using FADN data	WASS/WUR	2013	1.5
B) General research related competences			
Techniques for writing and presenting a scientific paper	WGS	2011	1.2
'Milk price uncertainty and milk quota abolition and their effects on the uptake of agri-environmental schemes'	EAAE, Zurich	2011	1
'The farm specific effect of increased output price volatility on agricultural land use decisions'	Agrimba, Wageningen	2011	1
'Land and milk production: the dynamics of change during the milk quota regime'	EAAE PhD day, Leuven	2013	1
'From Crop to Farm-Specific Payment and Insurance: Modeling Impacts of the Evolution of the Common Agricultural Policy in the Netherlands'	IARFIC, Zurich	2014	1
'The dynamics of dairy land use change with respect to the milk quota regime.' and 'Analysing the trade-offs between insurance and direct payment schemes: a farm modelling approach'	EAAE Congress, Ljubljana	2014	1
'Effects of volatile output prices on land-use change in agriculture'	WASS PhD day	2012	1
'Land and milk production: the dynamics of change during the milk quota regime'	WASS PhD day	2013	1
'The impact of whole farm income insurance on land use decisions: Modeling risk management for Dutch arable farmers'	Cluster Economics, WUR	2014	1
Supervision Master student	Wageningen University	2012 -2013	1
Assistant practical's and tests Economics of Agribusiness (AEP-20306)	Wageningen University	2012-2013	3
C) Career related competences/personal development			
Career Perspectives	WGS	2014	1.6
Total			36.8

*One credit according to ECTS is on average equivalent to 28 hours of study load

Colophon

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