Micro-economic panel data models for Dutch dairy farming

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Abstract

In The Netherlands, the dairy sector is the largest agricultural sub-sector based on both gross production value and number of farms. It is characterised by family farms in which large part of labour, management and risk bearing capital are supplied by the owner and his or her household. The dairy sector is highly regulated by the Common Agricultural Policy (CAP) of the EU. Within the CAP, milk production is limited since 1984 by farm specific quotas. The 2003 CAP reform, by introducing direct income payments, makes policies even more farm specific. To understand how individual family farms react to policy changes it is necessary to develop farm specific models. This is done using panel data and generalised method of moments (GMM) econometric estimation, keeping account of endogeneity, sample selection and unobserved farm specific effects. The estimated models describe milk production, on- and off-farm labour supply, investment in machinery, exit from, and growth in milk production. The models are used to understand how Dutch dairy farms react on the 2003 CAP reform.

Results show a strong decrease of income on Dutch dairy farms due to the milk price decrease resulting from the 2003 CAP reform. Results are calculated without taking structural changes in Dutch dairy farming into account. However, results show that due to the milk price decrease the number of milk producing farms decreases and that it will be mainly small farms that exit. This leaves possibilities for remaining farms to grow and take advantage of the better earning capabilities of larger farms. In total the effect on income for the remaining farms is therefore less strong than calculated in a situation without structural change.

Decoupled payments are advocated by the World Trade Organization (WTO) as a way to transfer income to farmers with minimal potential to distort production and trade. However, theoretically decoupled payments can impact production through an income effect changing on- and off-farm labour supply. We do not find such an effect of decoupled payments on both on- and off-farm labour supplies and therefore production.

A new way of modelling the impact of financial variables on investment decisions is proposed. Estimation results show that financial variables do not have a significant effect on investment in machinery. So, direct income payments, as proposed in the 2003 CAP reform, do not affect investment in machinery in case these payments lead to changes in e.g. solvability or liquidity.

Key words: micro-economic models, panel data, GMM, CAP reform, dairy farming

Voorwoord/Preface

Gedurende een groot deel van mijn leven heb ik mijn vakantiedagen op de boerderij van een oom en tante van mijn vader doorgebracht. Door de hier opgedane ervaringen was de landbouwsector het eerste waar ik aan dacht toen ik na mijn studie een onderwerp zocht om mijn kennis op toe te passen. Het enthousiasme voor onderzoek was ondertussen ontstaan tijdens de studie algemene econometrie aan de Erasmus Universiteit Rotterdam. Ik was verheugd dat Arie Oskam en Jack Peerlings mij aanboden een promotieonderzoek te komen doen bij de vakgroep Agrarische Economie en Plattelandsbeleid van Wageningen Universiteit. Dit proefschrift is het resultaat van dat onderzoek. Dit voorwoord is in het Engels geschreven wanneer het niet-Nederlandstaligen betreft.

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Daan Ooms

Utrecht, januari 2007

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Chapter 1 Introduction

General background

In The Netherlands, the dairy sector is the largest agricultural sub-sector based on both gross production value and number of farms[1]. It is characterised by family farms in which large part of labour, management and risk bearing capital are supplied by the owner and his or her household. The dairy sector is highly regulated by the Common Agricultural Policy (CAP) of the EU. Within the CAP, milk production is limited since 1984 by farm specific quotas. The 2003 CAP reform, by introducing direct income payments, makes policies even more farm specific. To understand how individual family farms react to policy changes it is necessary to develop farm specific models.

Policy change

On June 26 2003 the European ministers of agriculture agreed on a reform of the CAP (European Commission, 2003). A prolongation of the milk quota system until 2014/15 was agreed, in combination with a 1.5 per cent milk quota increase. The reform entails further a stepwise reduction in intervention prices for skimmed milk powder of in total 15 per cent and 25 per cent for butter. For the Dutch dairy sector this is expected to result in a decline in the price for milk farms receive. To compensate farms for the expected loss in income coupled direct income payments, stepwise increasing to €35.5 per ton were announced. From 2007 on these direct income payments will be decoupled. Direct payments are provided under cross-compliance restrictions; this implies that full direct payments can only be obtained if the farm complies with certain criteria. The introduction of direct income payments with cross-compliance requirements is a new policy instrument within the CAP for the dairy sector. The cross-compliance requirements were not exactly clear at the time this research was performed. The direct income payments influence income of family farms. Theoretically, the change in income on family farms has an impact on the choices made in the household and production part of the family farm (see e.g. Hennessy, 1998 and Findeis, 2002). Given the importance of the Dutch dairy sector it is important to understand how family farms react to the 2003 CAP reform. Models used for that purpose should take interrelation of choices in the household and production part of the family farm into account. Moreover, these models should be able to deal with the farm specific nature of the direct income payments. Household production

[1] See Tables 7.1 and 7.14 in Landbouw-Economisch Bericht (2006).

models seem to be the logical candidate for this type of analysis.

Household production models

A household production model is a model that consists of two parts: the household and the production part. Singh et al. (1986) provide an overview on the characteristics and estimation of household production models. They also describe applications in which the usefulness of household production models for understanding the effects policy changes becomes apparent. A household production model keeps account of the interdependence between production and consumption decisions. For example the small increase in quota in the CAP 2003 reform will have an effect on the production part and through that on the income entering the household part. Moreover, the expected decline in milk price and the introduction of direct income payments will have an additional effect on income. It is expected that total income from farming declines ceteris paribus due to the CAP 2003 reform. This effect on the household part can affect the production part through a change in for example time allocated to farm work and money available for investments. This can have an effect on the growth of farms and influence their chance of exit from production. The household production model describes interdependencies between the household and the production part theoretically in a complex system of equations. Unfortunately this system is too complex to estimate as a whole. However, it is possible to estimate separate parts of this system taking the interdependence with other parts into account (e.g. Elhorst, 1994; Kimhi and Bollman, 1999 and Goodwin and Mishra, 2004). The strong link between the household and production part of the family farm, current policy instruments and the 2003 CAP reform raise several issues with respect to the consequences of the CAP reform for the dairy sector.

Issues

A farm household allocates labour and capital to the production part of the farm. In return the household receives the profit of the farm. This is part of the income of the household, next to income from the allocation of labour and capital off-farm and income transfers. The expected decline in milk price and introduction of decoupled income payments as a consequence of CAP reform can be expected to change dairy farm income. This income change can have several consequences for the farm household. A decrease in income, for instance, can trigger the household to work more off-farm, to allocate more labour and capital on-farm to increase milk production, or both, to compensate the decrease in income. However, the decrease of income can also cause the farmer to exit milk production. If the increase in milk production is considered, household capital is used to acquire extra quota. Next to that the CAP reform includes a 1.5 per cent increase of quota. The increase in milk production can increase the demand for household labour and capital. The increased demand for household labour increases the marginal reward for labour used on-farm. This can have consequences for the amount of off-farm labour and leisure, and consequently on farm income. Income is also changed by the introduction of a direct income payment. However, this will increase income and causes opposite effects compared to the milk price decrease. Previous micro economic research on the effects of policy changes for Dutch dairy farming concentrates on the production part of the family farm. Boots (1999) for example looks at the consequences of alternative dairy policies for production decisions and income from farming. Another example is Peerlings and Polman (2004) who look at the joint production decisions of milk and wildlife and landscape as a result of the introduction of agricultural environmental schemes. This thesis investigates the effects of policy change on both the production and household parts of the family farm. The reasoning above shows that both parts of the family farm are influenced by the 2003 CAP reform. Even though this research covers both parts of the family farm, it is limited to the investigation of the effects on milk production and income, time allocation, investment and growth and exit of dairy production. Policy changes may work out in a different way for different farms. This calls for quantitative methods that take systematic differences between farms into account. A class of econometric methods that explicitly allow for this are based on the use of panel data.

Panel data

In The Netherlands, the LEI creates an extensive farm level panel data set, containing production and consumption variables, of dairy farms. The farms enter and leave the data set at different dates and also the length a farm is in the data set differs. This leads to an unbalanced, or rotating, panel data set. The LEI panel data set is used in this research. Some differences in e.g. income from farming and labour supply between farms are not explained by observable variables. Differences in e.g. managerial ability or soil quality can lead to different outcomes between farms. This causes farm specific heterogeneity. Unfortunately, it is not possible to estimate completely farm specific equations because of limited observations per farm. However, econometric methods not controlling for heterogeneity at all run the risk of obtaining biased results. With panel data models a compromise is found in assuming equal reactions to changes in variables, and keeping heterogeneity into account by introducing farm specific time invariant effects in estimable equations (Wooldridge, 2002, Chapter 10). Recent examples of the use of panel data models derived from household production theory in the agricultural economics literature are Foltz (2004) and Phimister et al. (2004). Estimation of panel data models is straightforward if the assumptions with respect to the data generating process needed to use Ordinary Least Squares (OLS) apply to the estimation. However, this is often not the case. Panel data estimation methods that do not depend on strong assumptions with respect to the data generating process are based on the Generalized Method of Moments (GMM). Therefore GMM will be used in this study.

GMM

The standard econometric modelling practice for a long time was founded on strong assumptions concerning the underlying data generating process. In contrast, the Generalised Method of Moments (GMM) estimator is a flexible tool applicable to a large number of models, which relies on mild and plausible assumptions (Hall, 2005: 2 and 49-55). It can be shown that well known estimators, like e.g. OLS and Two Stage Least Squares (2SLS), are special cases of the GMM estimator. Next to that, it is straightforward to generate heteroscedasticity and autocorrelation robust standard errors with GMM. Because of these advantages GMM is often used within the class of panel data estimation techniques. An example of this is the Arellano and Bond (1991) estimator using the time series element of panel data to estimate dynamic panel data models that can be used for typical dynamic models like growth models. Elements of the Arellano and Bond (1991) estimator based on GMM can also be used for the estimation of static models like a milk production function. The advantages of GMM can also be used to make existing methods developed for panel data less dependent on strong assumptions. An example of this is the attrition model in Wooldridge (2002: 585-587). This method is described using a 2SLS estimator that depends on strong assumptions. Replacing the 2SLS estimator with a GMM estimator based on the Arellano and Bond (1991) estimator eliminates the necessity for strong assumptions and makes the estimator broader applicable. This can be used within a model for the growth of farms taking the change of exit into account. A few examples of panel data methods based on GMM are Thijssen (1996), Chavas and Thomas (1999) and Shankar et al. (2003). Furthermore, these methods are not often used in agricultural economics.

Milk production and income

Production processes can be described by their technical economic characteristics like e.g. production and substitution elasticities and returns to scale. An estimated production function can be used to derive these characteristics. The derivation of technical economic characteristics from a production function has been performed before for Dutch dairy farming, see e.g. Thijssen (1992, Chapter 2) and Elhorst (1994). However, it is not performed for the period in which farmers produce under a quota regime. The switch from a period without quota constraints to a period with quota constraints can cause differences in the technical economic characteristics of milk production. It is not expected that these differences are large. However, for a good assessment of the effects of policy change it is essential to have up to date estimates of the characteristics. A production function is typically a description of the production part of the farm. The derivation of the production function does not require the full specification of a household production model. Demand equations for the inputs can be derived from the production function assuming profit maximisation. Important for the assessment of the consequences of the CAP reform is that farm profits that enter the household part of the farm as income can be derived from the estimated production function. Decoupled direct income payments enter the farm household part directly and independent of the production part of the farm. So, even though we do not need the household production theory to derive the production function we can make use of it to assess the impact of the 2003 CAP reform. Using panel data estimation techniques allows for determining unknown farm specific effects (see e.g. Wooldridge, 2002: 251). These represent in this case for example managerial ability and soil quality. With the estimated production function including the farm specific effects and the derived input demand equations it is possible to simulate farm specific changes in production, input demand and farm income due to the 2003 CAP reform.

Time allocation

Time allocation is a typical topic in household economics (see e.g. Kooreman and Wunderink, 1996). In the household production model, time allocation is part of the household part of the model. However it is not independent of the production part. Examples of applied time allocation models derived from the agricultural household production model are Woldehanna et al. (2000) and Goodwin and Mishra (2004). Both these examples estimate labour supply equations. In the remainder of this thesis the term labour supply is used for time allocated to labour. One of the elements of time allocation is labour supplied to the farm. This results in an internal labour market that is cleared by an internal wage. The 2003 CAP reform can change this internal wage due to the increase in quota. This would result in a change in on-farm labour supply, which changes time allocated to leisure or off-farm labour supply. Another element influencing time allocation of a household is income. The 2003 CAP reform changes income due to an expected decline of farm profit and the introduction of direct income payments. Another element of time allocation is off-farm labour supply. Not all farms supply off-farm labour. This causes sample selection that has to be taken into account in estimation (e.g. Wooldridge, 2002: 551-552). From the household production model on- and off-farm labour supply equations can be derived (see e.g. Huffman, 1980 and Kimhi and Lee, 1996). Estimating these equations using panel data techniques allows for farm specific effects in labour supply for which no data exist. These represent in this case for example preference for a high living standard or preference for working on a farm. With the estimated labour supply equations including the farm specific effects it is possible to simulate farm specific changes in labour supply due to the different elements in the 2003 CAP reform like the expected milk price decrease and the introduction of direct income payments. There is no general consensus about these effects in literature. Findeis (2002), for example, shows in a theoretical household production model that income transfers reduce total working time, whereas Hennessy (1998) shows the possibility of an increase in on-farm labour due to direct income payments, in his theoretical model.

Investment

In the long run farmers can adjust their production possibilities by investments in the capital stock. See e.g. Chirinko (1993), Bond and Meghir (1994) and Gardebroek (2004) for applied work on investments in agriculture. Whereas in adjusting variable inputs short-run economic considerations are important, investment decisions are usually based on the expected long-term economic situation. Firms compare the expected long-term benefits of new capital goods with their current and future costs and then decide whether to invest or not. Investments therefore also reflect the expectations firms have on the economic future. As with on farm labour the return on capital is expected to decline due to the price decrease in the 2003 CAP reform. Most investments on farms are large and require loans. To give a loan banks also form an expectation of the economic future of a farm. For a bank it is important whether a farm is able to earn enough in the future to payback the loan. To assess this, a bank makes use of the financial variables of a farm like debt, solvability and liquidity. In empirical research, financial variables are shown to have a possible impact on investment decisions (see Hubbard (1998) for an overview). The expected decline of farm income and the introduction of direct income payments have an effect on income. Through income they have an effect on financial variables. If financial variables have an effect on investment decisions, the direct income payments within the 2003 CAP reform can change production possibilities in the long run. This would reject the assumption of minimally distorting direct income payments made by the

WTO (USDA, 2003). Estimating investment equations using panel data techniques allows for farm specific effects. These represent in this case for example managerial ability and the preferences for new technology.

Farm growth and exit

The structure of Dutch dairy farming is changing. The number of dairy farms is decreasing. At the same time the average size is increasing (CBS/LEI, 2006). Examples of applied research on the growth of individual farms are Weiss (1998) and Foltz (2004). The 2003 CAP reform is expected to change income. A change in income affects many choices of the household. For example it changes the demand for leisure. A change of this has an impact on the supply of labour and can therefore affect the production part of the farm through a change of on-farm labour. This can influence growth of the production part. Growth is typically a dynamic process. The dynamic panel data estimation technique of Arellano and Bond (1991) has shown to be a suitable technique for dynamic models, see e.g. Thijssen (1996) and Rizov (2005). In this research we are interested in the level of milk production, and therefore, use milk output as a size measure. It is expected that decisions on milk output are made simultaneously with decisions on factor inputs. Moreover, decisions on milk output influence farm income and might therefore be made simultaneously with decisions on other income sources. This can lead to endogeneity that has to be taken into account in estimation (see e.g. Wooldridge, 2002: 83). The Arellano and Bond estimator allows for endogenous variables. Estimating a farm growth model using this estimator also allows for taking into account farm specific effects. These can represent in this case a wide range of unobserved characteristics. Examples of these are managerial ability that allows farmers to benefit from the possibilities of economies of scale, but also household preferences. With an estimated growth model including the farm specific effects it is possible to make farm specific statements about the effects of the 2003 CAP reform.

An extreme form of negative growth is exit. Exit from milk production is however a fundamentally different decision than decreasing it. The exit decision is a definite decision and is typically modelled as a binary choice. Examples of exit equations in agriculture are Kimhi and Bollman (1999) and Foltz (2004). In exit literature, a decision to exit given present information leads to an immediate exit. However, exit as a large disinvestment can take time to be effective. Therefore, it is also interesting to look at exit in the medium term given present information.

Summary of Research Objectives

The general objective of this research is to estimate models based on a household production model for Dutch dairy farms producing under a quota regime, using panel data and GMM, keeping account of special features in estimation like endogeneity, sample selection and unobserved farm specific effects in order to in order to understand how Dutch dairy farmers are expected to react on the 2003 CAP reform. To reach the general objective, the following specific objectives are formulated:

1. Estimate the production function for milk avoiding the endogeneity problem by using GMM as estimation method and using the estimation to determine the economic effects of the EU 2003 dairy policy reform for individual dairy farms and dairy farming as a whole in the Netherlands (Chapter 2).
2. Determine the effect on on-farm and off-farm labour of decoupled payments as part of the 2003 CAP reform based on the estimation of reduced form on-farm and off-farm labour supply equations for Dutch dairy farmers using panel data estimation techniques and taking possible sample selection in the off-farm labour supply equation into account (Chapter 3).
3. Investigate the effect of financial variables on investment of Dutch dairy farmers, using an Euler equation approach in which financial variables are explicitly included in the optimality conditions for investments and see whether the 2003 CAP reform has an effect on investments through its effect on financial variables (Chapter 4).
4. Determine the characteristics of Dutch dairy farms that influence growth and exit using estimation techniques that take the dynamic nature of growth and the definite nature of exit into account and use these models to make statements about the effects of the 2003 CAP reform on growth and exit (Chapter 5).

Chapter 2 Effects of EU dairy policy reform for Dutch dairy farming: a primal approach using GMM estimation[1]

2.1 Introduction

On 26 June 2003 the European ministers of agriculture agreed on a reform of the Common Agricultural Policy (CAP) (European Commission, 2003). The reform entails a reduction in intervention prices for skimmed milk powder of 15 per cent (in three yearly steps of 5 per cent from 2004 to 2006) and 25 per cent for butter (three yearly steps of 7 per cent from 2004 to 2006 and 4 per cent in 2007). In addition, a prolongation of the milk quota system until 2014/15 was agreed, in combination with a milk quota increase of 1.5 per cent in three yearly steps of 0.5 per cent starting in 2006. No further quota increases were announced, but a market report considering further quota increases will be presented once the reform is fully implemented. As a further precaution against a possible surge in butter intervention post EU enlargement, a new butter intervention ceiling was set at 70 thousand tons in 2004/05, with an annual cut of 10,000t until it reaches 30,000t in 2008/09. Finally, a decoupled direct income payment of €35.5 per ton was announced. In the Netherlands, there is a strong interest in the possible effects of dairy policy reform given the economic importance of the dairy industry.

In previous research on the effects of dairy policy reform, micro-econometric simulation models have played an important role (see e.g. Zepeda et al., 1991 and Boots and Peerlings, 1999). Micro-econometric models are defined as a set of behavioural relationships that are based on microeconomic theory and estimated using farm (panel) data using econometric techniques. Micro-econometric models usually start with specifying a profit function from which input demand, output supply and shadow prices of quasi-fixed factors are derived (for an overview, see Oude Lansink and Peerlings, 2001). This is the so-called dual approach, which uses prices of variable inputs and outputs and quantities of quasi-fixed inputs in estimation. Multicollinearity among the prices of the (small number of) variable inputs and outputs is likely, because the available prices do not vary between farms. An alternative is the primal approach, where the production function using quantities of all inputs is estimated. These quantities *do* vary between farms in the available data set. The first-order conditions for profit maximisation provide a model of input demands; output supplies and shadow price equations of quasi-fixed inputs (see Thijssen (1992, Chapter 2) for an application of the primal approach). An advantage of estimating the primal model is that variables do not have

[1] Improved version of Ooms, D.L. and Peerlings, J.H.M. (2005) *European Review of Agricultural Economics* 32: 517-537

to be categorised as either fixed or variable, because the primal model treats both kinds of variables the same.

Estimating the production function with direct estimation methods like ordinary least squares requires inputs to be exogenous[2]. Variables are often classified as exogenous or endogenous based on economic reasoning (see e.g. Thijssen, 1992, Chapter 2 and Elhorst, 1994). Such a classification is by definition rather arbitrary. This has led analysts to base classification largely, but not solely, on statistical grounds (Greene, 1993: 288)[3]. Possible endogeneity calls for instrumental variable (IV) estimation (Greene, 1993: 288). An example of IV estimation of a production function in agriculture is found in Thijssen (1992, Chapter 2), who uses Three Stage Least Squares (3SLS). Another IV estimator is the Generalised Method of Moments (GMM). The advantage of GMM over other IV estimators, like 3SLS, is that GMM does not require strong assumptions about the underlying data generating process and has the ability to generate standard errors that are robust with respect to heteroscedasticity and autocorrelation. Other IV estimators, like 3SLS, are a special case of GMM. So GMM is valid in more cases than other IV estimators are (compare the discussion on Maximum Likelihood Estimation (MLE) and GMM in Hall, 2005: 108-114). To the best of our knowledge, GMM has not been used in the empirical agricultural economics literature to estimate production functions.

The purpose of this paper is to estimate the production function for milk avoiding the endogeneity problem by using GMM as estimation method and using the estimation to determine the economic effects of the EU 2003 dairy policy reform for individual dairy farms and dairy farming as a whole in the Netherlands.

Section 2.2 presents the theoretical primal model in the case of a supply quota. The empirical model is discussed in section 2.3. Section 2.4 presents the data. Section 2.5 describes the estimation method and results. The model developed is used to derive the economic effects for dairy farming of EU dairy policy reform in section 2.6. Section 2.7 summarises the main results and provides some conclusions.

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[2] Exogenous variables are explanatory variables that are determined independently of the dependent variable in the same time period.
[3] See Mundlak (1996) for a discussion of endogeneity in production functions.

2.2 Theoretical model

If the production function is known, the first-order conditions for profit maximisation can be derived. From these first-order conditions functions for output supply, variable input demands and shadow prices of quasi-fixed inputs can be derived, assuming price-taking behaviour in input and output markets. Thus, the farm is assumed to be in static equilibrium with respect to outputs and variable inputs, conditional on the level of quasi-fixed inputs and prices of outputs and variable inputs.

The production function shows the relationship between output and inputs, for a given technology. Unlike its corresponding profit function, the specification of the production function is the same whether or not the output is constrained by quota.

The technology for dairy farm *h* can be represented by the following function *g*:

$$g(\mathbf{q}_{ht}, \mathbf{x}_{ht}) = 0 \qquad (2.1)$$

where $\mathbf{q}_{ht}$ is a vector containing the quantities of unconstrained and constrained outputs for farm *h* at time *t*, and $\mathbf{x}_{ht}$ is a vector that contains the quantities of both variable and quasi-fixed inputs for farm *h* at time *t*.

A production function describes the transformation of inputs into a single output, and does not normally accommodate multiple outputs. Moreover, with multiple outputs it is also not possible to distinguish the allocation of inputs to individual outputs. To deal with this we choose one output of interest, q_{mht} (milk). Under the assumption of separability of milk output and other outputs, the vector of other outputs, $\mathbf{q}_{\mathbf{l}ht}$, is transferred to the right hand side of equation (2.1). The production function for q_{mht} then becomes:

$$q_{mht} = f(\mathbf{x_{ht}}, -\mathbf{q_{lht}}) \qquad (2.2)$$

The production technology has to satisfy certain regularity conditions (see Chambers, 1988: 9) which imply that the production function is non-decreasing in inputs, concave, non-negative, continuous and twice differentiable.

Under profit maximisation, the first derivative of the production function with respect to an input times the output price (marginal revenue of the input) should equal the corresponding input price (marginal cost of the input):

$$\frac{\partial f(\mathbf{x}_{ht}, -\mathbf{q}_{lht})}{\partial x_{jht}} \times p_{mht} = w_{jht} \qquad j = 1,2,..,J \qquad (2.3)$$

where p_{mht} is the price of the output of interest for farm *h* at time *t*, and *J* is the total number of inputs. In the case of a variable input, w_{jht} is the market price associated with variable input *j* for farm *h* at time *t*. In the case of a quasi-fixed input, w_{jht} is the shadow price of quasi-fixed input *j* for farm *h* at time *t*.

Another requirement of profit maximisation is that the first derivative of the production function with respect to one of the other outputs, incorporated in the production function, times the output price of the output of interest equals the output price of the other output:

$$\frac{\partial f(\mathbf{x}_{ht}, -\mathbf{q}_{1ht})}{\partial q_{kht}} \times p_{mht} = -p_{kht} \qquad k = 1,2,..,K \qquad (2.4)$$

where p_{kht} is the market price of other output *k* for farm *h* at time *t*, and *K* is the number of other outputs. p_{kht} has a negative sign because of the negative sign of $\mathbf{q}_{1ht}$.

A problem in the case of a constrained output is that p_{mht} is unknown because it is the price at which a farm *h* would be willing to produce the quota amount (the shadow price of production). This price cannot be observed. In the case of tradable quota rights (as in the Netherlands) the shadow price of production could be calculated by subtracting the lease price (market price) of the quota rights from the market price of the constrained output (see Appendix 2.A). In that case, the shadow price of production is equal among farms. However, equal marginal cost of milk production for all dairy farms seems an unrealistic assumption. There is some evidence that quota supply is price-inelastic, which leads to a situation where only farms with a relatively high unit quota rent buy or lease-in quotas. Farms with relatively high marginal cost of production might not sell or lease-out quotas because of adjustments costs or the lack of alternative use for their fixed factors. So, farms do not have the same marginal cost of production.

An alternative approach is to calculate farm-specific shadow prices of milk production using the *n* first-order conditions for profit maximisation for the variable inputs (see equation (2.3)) and the production function (in total *n+1* equations). Taking the prices of the variable inputs and quantities of quasi-fixed inputs, milk and other output as exogenous, this set of *n+1* simultaneous equations can be solved for the shadow price of milk production and the quantities of the variable inputs (*n+1* unknowns).

The variable input prices are calculated using the *n* first-order conditions for the *average* dairy farm. For the average dairy farm we assume the shadow price of production equals the milk price minus the lease price of milk in 1999/00. Quantities of variable inputs are assumed fixed. This results in the shadow prices of variable inputs. We now take the shadow prices of variable inputs of the average farm as market prices of the variable inputs and use these prices in our simulations. The average unit quota rent calculated by the model now equals the lease price in 1999/00. However, the unit quota rents, and therefore, the marginal costs differ between farms[4].

Besides production, we are also interested in short-term profit. In the case of a supply quota, we can separate profit into *profit linked to production* and the *quota rent* (the unit quota rent times milk production). This is shown graphically in Appendix 2.A.

2.3 Empirical model

To produce outputs, farm *h* at time *t* uses cattle (x_{1ht}), an aggregate of non-factor inputs (x_{2ht}) including feed, farm household labour (x_{3ht}), buildings (x_{4ht}), machinery (x_{5ht}), and land (x_{6ht}).The dairy farm produces milk (q_{mht}) and an aggregate of other outputs (q_{lht}). Minus q_{lht} is treated in the model as an input (x_{8ht}).To take technological change in *y* over time into account, a time trend (x_{7ht}) was included in the model.

We chose a symmetric quadratic production function because of its flexibility. The symmetric quadratic production function is continuous and twice differentiable in the variables. A farm-specific effect, α_{0h}, was added to the model to capture farm-specific differences in milk production. This farm-specific intercept reflects differences in farm characteristics (e.g. management quality and soil quality) and is assumed to be a fixed effect. An error term, e_{ht}, captures the difference between predicted and realised values of milk production. The empirical model then becomes:

[4] Taking the actual lease price probably underestimates the average marginal cost of production, and therefore, the calculated prices of the variable inputs. The reason is that with price-inelastic quota supply, only farms with relatively low marginal production cost buy or lease-in quotas. Since the set of first-order conditions is homogeneous of degree zero, the choice of another level of average marginal cost of production would not affect the optimal variable input demands or the percentage changes of the shadow prices of the fixed inputs in the simulations. The unit quota rent and profit changes, however, would be affected because the milk price is fixed and known. We investigated the impact of our assumptions in the sensitivity analysis presented in section 6.

$$q_{mht} = \alpha_{0h} + \sum_{j=1}^{8} \alpha_j x_{jht} + \frac{1}{2} \sum_{l=1}^{8} \sum_{j=1}^{8} \alpha_{lj} x_{lht} x_{jht} + e_{ht} \tag{2.5}$$

Equation (2.5) is estimated. For simulating policy impacts, the first-order conditions for profit maximisation are needed as well as the production function[5]. They are derived from the estimated production function and are not directly estimated. Not estimating the first-order conditions theoretically leads to a loss in efficiency. However, not estimating the first-order conditions avoids incorporating prices whose values are uncertain and which lack variability over farms in the cross section. This lack of variability was a problem in an attempt we made to estimate a system of input demand and output supply equations derived from the profit function.

The first-order conditions are:

$$\left(\alpha_j + \sum_{l=1}^{8} \alpha_{lj} x_{lht} \right) \times p_{mht} = w_{jht} \qquad j=1,2,\ldots,8 \tag{2.6}$$

where p_{mht} is the shadow price of milk output for farm h at time t and w_{jht} the (shadow) price of input j (other output when j is 8) for farm h at time t.

The shadow price of milk is used, because milk is produced under a quota system and is, therefore, quasi-fixed.

2.4 Data

We used an unbalanced panel data set provided by the LEI. In this data set, a farm is classified as a dairy farm if milk revenues comprise 50 per cent or more of its returns. The data set provided 5802 observations on 1176 farms for the period investigated, namely 1987/88 to 1999/00.

The model contains one supply-constrained output, one unconstrained output and seven inputs. The constrained output is milk (milk quota). The unconstrained output is an aggregate of revenues from marketable crops, veal, pigs, poultry and other farm revenues. The seven inputs are cattle, an aggregate of non-factor inputs, farm household labour, buildings, machinery, land and a time trend. Cattle is measured as the value of cows aged one year or

[5] Farm-specific levels of fixed input use, and therefore variable input use, and the farm-specific fixed effect provide farm-specific outcomes.

more. We used the value instead of the number of cows to take quality differences between cows into account. Aggregate non-factor input contains, amongst other things, feed, veterinary costs and hired labour. Farm household labour consists of total household labour measured in hours. The implicit quantities of other output, cattle, aggregate non-factor input, buildings and machinery are obtained by dividing the total values of these variables, as obtained from the aforementioned data set, by their corresponding Tornqvist price index. The price indices are constructed using the available farm level prices from the data set. If the farm level prices are not available price indices from CBS/LEI (2000) are used. Land is measured as the total area of farmland in hectares. The time trend is used to indicate the effect of the change in technology and has value 1 in the first year in the data set, 1987/88. Table 2.B1 in Appendix 2.B gives the units of measurement, mean and standard deviation of the variables used. The data set also contains information on income variables. We use information on income from farming and total farm household income in the simulations in section 2.6. Income from farming is defined as revenue minus variable costs (=profit) minus paid costs for land and capital and capital depreciation. So income from farming is the return on land, labour and capital supplied by the farm household. Total farm household income equals income from farming plus net income from non-farming activities. Examples of non-farm income are wages for off-farm work, net returns on capital invested in e.g. houses, shares and bonds and social security payments. Non-farm income can be negative because of paid interest on mortgages and private loans.

2.5 Estimation and results

2.5.1 Estimation

The estimation method used is the Generalised Method of Moments (GMM). The advantage of GMM over traditional estimation methods like Ordinary Least Squares (OLS) and MLE is that GMM does not require strong assumptions on the underlying data generating process (Hall, 2005: 108-114). Another advantage of GMM is that it can be used when (suspected) endogenous regressors are present, since it is an instrumental variable estimator (Greene, 1993: 288).

The two step GMM estimation in this research is based on the moment condition:

$$E[\ddot{e}_{ht}\ddot{\mathbf{z}}_{ht}] = \mathbf{0} \tag{2.7}$$

for all h and t for which data are available. E is the expectation operator, $\ddot{e}_{ht}$ and $\ddot{\mathbf{z}}_{ht}$ are in deviation from means[6], and $\mathbf{z}_{ht}$ is a $q \times 1$ vector with instrument values for individual h at time t. The GMM estimator used to estimate the vector of unknown variables, $\boldsymbol{\theta}$, is

$$\hat{\boldsymbol{\theta}} = \mathbf{Q}^{-1}\left(\sum_{h=1}^{H}\ddot{\mathbf{x}}_h{}'\ddot{\mathbf{z}}_h\right)\left(\sum_{h=1}^{H}\ddot{\mathbf{z}}_h{}'\hat{\ddot{\mathbf{e}}}_h\hat{\ddot{\mathbf{e}}}_h{}'\ddot{\mathbf{z}}_h\right)^{-1}\left(\sum_{h=1}^{H}\ddot{\mathbf{z}}_h{}'\ddot{\mathbf{q}}_{\mathbf{m}h}\right) \tag{2.8}$$

where H is the number of farms in the data set, $\ddot{\mathbf{x}}_h = (\ddot{\mathbf{x}}_{h1},...,\ddot{\mathbf{x}}_{hT})'$, T is the total number of time periods in the data set, $\mathbf{x}_{ht}$ is a p × 1 vector of explanatory variables, $\ddot{\mathbf{z}}_h = (\ddot{\mathbf{z}}_{h1},...,\ddot{\mathbf{z}}_{hT})'$, $\ddot{\mathbf{q}}_{\mathbf{m}h} = (\ddot{q}_{mh1},...,\ddot{q}_{mhT})'$, $\ddot{\mathbf{e}}_h = (\ddot{e}_{h1},...,\ddot{e}_{hT})'$,

$$\mathbf{Q} = \left(\sum_{h=1}^{H}\ddot{\mathbf{x}}_h{}'\ddot{\mathbf{z}}_h\right)\left(\sum_{h=1}^{H}\ddot{\mathbf{z}}_h{}'\hat{\ddot{\mathbf{e}}}_h\hat{\ddot{\mathbf{e}}}_h{}'\ddot{\mathbf{z}}_h\right)^{-1}\left(\sum_{h=1}^{H}\ddot{\mathbf{z}}_h{}'\ddot{\mathbf{x}}_h\right) \tag{2.9}$$

and $\hat{\ddot{\mathbf{e}}}_h$ is created with a first step estimator of $\boldsymbol{\theta}$ using equations (2.8) and (2.9) without the term $\hat{\ddot{\mathbf{e}}}_h\hat{\ddot{\mathbf{e}}}_h{}'$. The approximate large sample variance for the estimator is:

$$\mathbf{V} = \mathbf{Q}^{-1} \tag{2.10}$$

In this research we have an unbalanced data set. If there is no observation for farm h at time t, its corresponding variables are zero in the equations above. Variables are transformed to deviations from their means in order to lose the farm-specific effect, α_{0h}, from equation (2.5). The farm-specific effect for farm h can be recovered using equation (2.5), the parameter estimates and the values of the variables for one specific year or the means over some years[7]. It can be shown that using the regressors themselves as instruments gives the OLS estimator.

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[6] For example: $\ddot{e}_{ht} = e_{ht} - \bar{e}_h$ and $\bar{e}_h = \frac{1}{T_h}\sum_{t=1}^{T} e_{ht}$, where T is the total number of time periods in the data set, T_h is the total number of time periods household h is in the data set and $e_{ht} = 0$ if household h is not in the data set at time t.

[7] In the simulations in section 6 we use farm-specific observations for 1999/00 making the simulated and actual values of milk production equal in the base run.

To see whether the initial structure of the model is correct, we use Sargan's *J*-test of overidentifying restrictions (Hall, 2005: 47). If there are q moment conditions[8] and p parameters, there are q - p overidentifying restrictions. In Sargan's J-test:

$$J = \left(\sum_{h=1}^{H} \hat{\hat{\boldsymbol{\varepsilon}}}_h ' \ddot{\mathbf{z}}_h \right) \left(\sum_{h=1}^{H} \ddot{\mathbf{z}}_h ' \hat{\hat{\mathbf{e}}}_h \hat{\hat{\mathbf{e}}}_h ' \ddot{\mathbf{z}}_h \right)^{-1} \left(\sum_{h=1}^{H} \ddot{\mathbf{z}}_h ' \hat{\hat{\boldsymbol{\varepsilon}}}_h \right) \tag{2.11}$$

where $\hat{\hat{\boldsymbol{\varepsilon}}}_h$ is the vector of residuals created with $\hat{\boldsymbol{\theta}}$ of equation 2.8. The null hypothesis of this test is that the over-identifying restrictions hold, and hence that the initial structure of the model is correct. The test statistic has a χ^2_{q-p} distribution under the null-hypothesis.

The choice of endogenous variables in the model is often based on economic theoretical arguments (e.g. Thijssen, 1992, Chapter 2 and Elhorst, 1994). It is also possible to test for the impact of erroneously treating endogenous variables as exogenous. Endogeneity of a variable is taken into account by dropping this variable from the instrument set in the instrumental variable estimation in this research. A test for endogeneity of certain variables is described in Hausman (1978). The test statistic is

$$H = \left(\tilde{\boldsymbol{\theta}} - \hat{\boldsymbol{\theta}}\right)' \left(\hat{\mathbf{V}} - \tilde{\mathbf{V}}\right)^{-1} \left(\tilde{\boldsymbol{\theta}} - \hat{\boldsymbol{\theta}}\right) \tag{2.12}$$

where $\tilde{\boldsymbol{\theta}}$ is the parameter vector resulting from the unrestricted estimation in which the possible endogeneity of the variables under investigation is not taken into account and so these variables are still in the instrument set[9], $\hat{\boldsymbol{\theta}}$ is the parameter vector resulting from the restricted GMM estimation in which the variables under investigation are dropped from the instrument set. $\hat{\mathbf{V}}$ is given in equation (2.10) and $\tilde{\mathbf{V}}$ is a consistent estimators of the asymptotic covariance of $\tilde{\boldsymbol{\theta}}$. This is either the OLS variance matrix estimator or (2.10) in the case $\tilde{\boldsymbol{\theta}}$ is estimated with the two step GMM approach described above.

[8] This means that there are q instruments.

[9] When testing for endogeneity of one variable in a model where all other regressors are exogenous, this is OLS estimation. When testing for endogeneity of one or more variables in a model containing variables that are already concluded to be endogenous, this is a GMM estimation approach.

This test is distributed as χ_p^2, where p is the number of parameters in $\boldsymbol{\theta}$. The restricted GMM estimator is consistent in the presence of endogenous regressors, whereas the unrestricted estimator is not. The null hypothesis is:

$$\text{plim}\left(\tilde{\boldsymbol{\theta}} - \hat{\boldsymbol{\theta}}\right) = \mathbf{0} \tag{2.13}$$

Under the alternative hypothesis the equality in (2.13) does not hold. If the null hypothesis is not rejected, exogeneity of the variables under investigation is accepted. Rejection of the null hypothesis indicates endogeneity. In practice, a rejection of the null hypothesis is treated as acceptance of endogeneity. Using the Hausman test for small samples, as in this research, can result in negative test values. These are impossible to interpret, because the χ^2 distribution is defined only on non-negative values. One way to deal with negative Hausman test values is the approach of Browning and Meghir (1991). They do not use the whole parameter set in (2.12), but only the parameters corresponding to the possible endogenous variables. This ignores parts of the estimated models and is, therefore, not preferred. Another way to deal with negative Hausman test values is to use the LR statistic described by Hall (2005: 153-161) for hypothesis testing in models estimated by single equation GMM. The instrument set for the unrestricted model, $\mathbf{z}_{ht}^{u}$, contains the possibly endogenous variables. The instrument set for the restricted model, $\mathbf{z}_{ht}^{r}$, does not contain the possibly endogenous variables. If the possibly endogenous variables are actually exogenous, both instrument sets are valid. If not only $\mathbf{z}_{ht}^{r}$ is valid. Therefore, the null-hypothesis of the LR-test is:

$$E[\ddot{e}_{ht}\ddot{\mathbf{z}}_{ht}^{r}] \;=\; \mathbf{0} \qquad \text{and} \qquad E[\ddot{e}_{ht}\ddot{\mathbf{z}}_{ht}^{u}] \;=\; \mathbf{0} \tag{2.14}$$

And the alternative hypothesis is:

$$E[\ddot{e}_{ht}\ddot{\mathbf{z}}_{ht}^{r}] \;=\; \mathbf{0} \qquad \text{and} \qquad E[\ddot{e}_{ht}\ddot{\mathbf{z}}_{ht}^{u}] \;\neq\; \mathbf{0} \tag{2.15}$$

The test statistic is:

$$LR = J^u - J^r \tag{2.16}$$

where J^u is Sargan's *J*-statistic for the unrestricted model and J^r is Sargan's *J*-statistic for the restricted model.

LR is distributed as χ_k^2 with *k* the number of restrictions in the restricted model i.e. the number of variables dropped from the instrument set of the unrestricted model. If a variable is endogenous, the second equality in (2.14) does not hold. This will lead to a higher value of the *J*-statistic in the unrestricted model and will, therefore, increase LR. The advantage of this approach, over that of Browning and Meghir (1991), is that it compares the whole restricted and unrestricted models.

2.5.2 Estimation results

In a production function, explanatory variables that are determined simultaneously with output are considered to be endogenous. For this reason cattle, farm household labour and aggregate non-factor input, containing feed, may possibly be endogenous variables (Thijssen, 1992, Chapter 2 and Elhorst, 1994), as well as other output since other output might compete for quasi-fixed inputs with milk production. On the other hand, a major part of other output is pork, poultry and egg production and arable farming. Decisions about these outputs do not have to be made simultaneously with decisions on milk production *per se*. For the Hausman test, a GMM estimate of the model is compared with the OLS estimate[10]. The instruments used for GMM estimation throughout this paper are: all exogenous variables and the products of total farm size[11] with all exogenous variables. Table 2.1 gives an overview of the exogeneity tests performed. The Hausman test (see equation (2.12)) for the exogeneity of the aggregate non-factor input results in a negative test value. Since the J-statistic does not exist for a model estimated with OLS, we have to rely on the approach of Browning and Meghir (1991) to make a statement about the exogeneity of aggregate non-factor input. This approach results in a test statistic of 4.27, which exceeds the 5 per cent critical value for the χ_1^2 distribution (3.84). The null hypothesis that aggregate non-factor input is exogenous is rejected. For this reason we treat aggregate non-factor input as endogenous when estimating.

[10] For this situation the LR-statistic is not defined, because the OLS estimate does not produce a J-statistic.
[11] Farm size is measured in nge (Dutch size unit) which is based on the potential profit per unit of cattle or hectares of certain crops.

Possible other endogenous variables are the cross terms of aggregate non-factor input with the other inputs. To test for this, the Hausman test (2.12) is applied to compare the model where aggregate non-factor input together with the cross terms are considered endogenous with the model where only aggregate non-factor input is considered endogenous. This results in a test statistic of 12.55. This does not exceed the 5 per cent critical value of the χ^2_{44} distribution (60.48). Based on this result, we conclude that the cross terms are exogenous. The test value for the Hausman test, where the endogeneity of farm household labour is considered together with the endogeneity of aggregate non-factor input, results in a negative test value. The value of the LR statistic (2.16) is 0.26, which is lower than the 5 per cent critical value for the χ^2_2 distribution (5.99). We therefore conclude that farm household labour is exogenous. The test value for the Hausman test (2.12), where the endogeneity of, respectively, cattle and other output is considered together with the endogeneity of aggregate non-factor input, are 10.02 and 1.86, which are lower than the 5 per cent critical value of the χ^2_{44} distribution (60.48). For this reason, we only treat aggregate non-factor input as endogenous in estimation.

Table 2.1: Results of exogeneity tests. Test values with 5 per cent critical values in brackets.

Test for exogeneity of:	Against model with the endogenous variables:	Hausman test result	LR-test result	Browning and Meghir test result	Conclusion
Aggregate non-factor input	None	Negative		4.27 (3.84)	Exogeneity rejected
Cross terms aggregate non-factor inputs	aggregate non-factor input	12.55 (60.48)			Exogeneity accepted
Farm household labour	aggregate non-factor input	Negative	0.26 (5.99)		Exogeneity accepted
Cattle	aggregate non-factor input	10.02 (60.48)			Exogeneity accepted
Other output	aggregate non-factor input	1.86 (60.48)			Exogeneity accepted

Sargan's J-test value (2.11) for the model, treating aggregate non-factor input as endogenous, is 43.03. This value does not exceed the 5 per cent critical value for the χ^2_{42} distribution (58.1). Therefore the model is not rejected. Table 2.C1 in Appendix 2.C gives the parameter estimates. The production elasticities and shadow prices derived from the estimated model are plausible (see Table 2.D1 and 2.D2 in Appendix 2.D) and comparable to those found by Boots and Peerlings (1999) and Thijssen (1992: 26) for Dutch dairy farming. The estimated returns to scale calculated with the average values of the variables are 1.02, which according to a *t*-test is not statistically different from one (p = 0.45). This indicates constant returns to scale in Dutch dairy farming. Boots (1999: 65) and Thijssen (1992: 26) both find evidence for increasing returns to scale. Both of these results were based on estimated models using data of earlier years than in our data set. Our result suggests that returns to scale were diminishing over time for Dutch dairy farmers.

2.6 Policy simulations and results

2.6.1 Policy simulations

In this section we use the GMM-estimated model to simulate the effects on Dutch dairy farming of the CAP reform of June 26, 2003. As the base run, we take the actual situation in 1999/00, the last year for which we have data. We calculate the effects as if the reform was fully implemented in 1999/00; thus, we do not take the phased introduction of reforms or dynamic effects (e.g. structural changes) into account. We show results with and without direct payments. The reason for this is that the direct payments are made conditional on ‘good farming practices’ (cross-compliance), but these are not defined yet in the Netherlands. Moreover, the Dutch government could decide to use part of the direct income payments for purposes other than supporting dairy farms but there is still uncertainty in the Netherlands about this modulation. Direct income payments will be decoupled in 2007 in the Netherlands.

Although we calculate for each individual farm in the sample the policy effects, we only present changes for three groups of farms. These groups are the 109 smallest farms, 110 largest farms and the 109 medium sized farms in the data set in the year 1999/00. Size is measured in milk production in 1999/00. In this year milk quotas where binding for all farms in the sample. During the simulations we keep the prices of variable inputs and the quantities of quasi-fixed inputs at their 1999/00 level. In all simulations other output is also fixed at its 1999/00 level because other output mainly represents activities that are not directly related to milk production.

We calculated the effects for the following scenarios:

S1: CAP reform. This scenario assumes a milk price reduction of 21 per cent. This is based on the intervention price cuts in the CAP reform for skimmed milk powder and butter of 15 per cent and 25 per cent respectively. To determine the milk price, we multiplied the intervention price reduction of skimmed milk powder and butter by 0.4 and 0.6 respectively, as is done in the Mid-Term Review proposals of the European Commission. The quota increase is 1.5 per cent. Direct income payments are 35.5 €/tonne. Aggregate non-factor input and cattle are assumed variable.

S2: As S1, except that we assume a 15 per cent price decrease in the milk price. This can be considered as a minimum price decrease.

2.6.2 Simulation results

Milk quotas are binding in both scenarios for all dairy farms, so the shadow price of production is smaller than the milk price for every dairy farm. Initially, the unit quota rent equals 16.2 euro cents per kg. With a 21 per cent milk price decrease this becomes 9.3 euro cents per kg, and with a milk price decrease of 15 per cent it is 11.3 euro cents per kg. This implies that the change in milk price does affect profit through a decrease in quota rent but does not affect variable input use or shadow prices of quasi-fixed inputs (see Appendix 2.A). So demand for variable inputs and shadow prices of quasi-fixed inputs (and other output) are completely determined by the quota amount. This result shows that Dutch dairy farms are seriously constrained by the milk quota system.

The increase in production can only be achieved by increasing the amount of aggregate non-factor input and cattle. To reach a milk output rise of 1.5 per cent, demand for the aggregate non-factor input increases by 2.2 per cent and cattle by 2.3 per cent on average (see Table 2.2). The increase in cattle exceeds the 1.5 per cent quota increase, which could be explained by the fact that productivity of milk cows decreases when total milk production increases. Although production and variable input use increase, the increase in the shadow price of production is small. This implies production can be increased at the quota level with only slightly increasing marginal cost.

Results show further that with an increase in milk production the shadow prices of land, machinery and farm household labour increase, while shadow price of buildings falls. Shadow prices are determined by the increase in milk production (positive effect) and the increase in demand for variable inputs (negative effect in case of substitutes; see Table 2.D3 in Appendix 2.D). Small farms have a very small shadow price for machinery. A small change in this shadow price due to policy change causes a large percentage change. The small shadow price suggests an overcapacity of machinery on small farms. The importance of other output varies substantially between farms. Comparable absolute changes can therefore lead to large percentage changes (e.g. for medium-sized farms in scenario S1). The (small) increases in the shadow prices of output, and especially the fall in milk price, reduce the unit quota rent[12]. This reduction is 42.3 per cent when output price decreases by 21 per cent (S1), and 30.3 per cent when output price decreases by 15 per cent (S2). Since we expect a price decrease somewhere between 15 and 21 per cent, the actual quota price decrease will be between 30.3 and 42.3 per cent.

Table 2.2: Percentage changes compared to the base run.

	S1 Average	S1 Small	S1 Medium	S1 Large	S2 Average
Milk production	1.5	1.5	1.5	1.5	1.5
Milk price	-21.0	-21.0	-21.0	-21.0	-15.0
Quantities:					
Cattle	2.3	1.3	2.1	3.2	2.3
Aggregate non-factor input	2.2	1.3	3.0	1.1	2.2
Shadow prices:					
Farm household labour	0.2	0.1	0.2	0.3	0.2
Buildings	-1.6	-0.2	-1.2	-4.7	-1.6
Machinery	2.8	61.0	2.9	2.1	2.8
Land	2.0	2.9	2.0	1.8	2.0
Other output	-10.9	-1.9	-96.8	-2.5	-10.9
Production	0.2	0.1	0.2	0.4	0.2
Quota (unit quota rent)	-42.3	-45.0	-42.8	-39.6	-30.3
Profit:					
Percentage change	-22.3	-18.2	-21.9	-23.9	-15.7
€/ tonne 1999 production	-67.1	-67.3	-67.2	-67.0	-47.2
€ /tonne new production†	-66.1	-66.3	-66.2	-66.0	-46.5

†new production is the production of 1999/00 plus the 1.5 per cent quota increase of the 2003 CAP reform

Profit was calculated by taking the value of outputs (milk and other output) and subtracting the value of aggregate non-factor input and costs of adjusting the cattle stock[13]. In S1 profit decreases on average by 22.3 per cent or €67.1 per tonne of milk in 1999/00 without the direct income payments (see Table 2.2). Therefore, on average a direct income payment of 35.5 €/tonne compensates about 53 per cent of the profit fall. In S2, this compensation is over 75 per cent. However, the profit fall could be larger if prices of the variable aggregate non-

[12] The shadow price of production changes which implies that also the unit quota rent will change. Because the change in the shadow price of output is farm-specific, it is to be expected that quotas will be traded from less efficient to more efficient farms.

[13]This definition takes the value of outputs minus the value of any purchased inputs plus the adjustment of the cattle stock.

factor input and cattle increase because of larger demand. Moreover, dairy farms have to meet the cross-compliance conditions to obtain the direct income payments. These conditions could imply extra costs. Furthermore, profit loss could be larger because the national government could decide to reduce direct payments in order to use the money for other purposes (modulation). Finally, direct income payments will be decoupled.

Assuming that the absolute profit change is equal to the change in income from farming and the change in total farm household income, the effect of the CAP reform on farm income can be calculated. Table 2.3 presents the percentages of dairy farms with negative income from farming, and with negative total farm household income, in the three size groups. It becomes clear from Table 2.3 that initially the percentage of dairy farms with negative income from farming is relatively high in the group of small dairy farms (14.7 per cent) and small in the group of large dairy farms (1.8 per cent). However, the difference in number of dairy farms with negative total household income is smaller, 3.7 per cent versus 0.9 per cent. Apparently, small dairy farms have more income from non-farming activities. In the large size group, there are more dairy farms with a negative total farm household income than a negative income from farming. This is caused by the fact that initially 20 dairy farms in this group have a negative non-farm income (in the small and medium-size group this is only 3 and 7 dairy farms respectively). This negative non-farm income is caused by interest payments (negative return on capital) on private loans and mortgages.

After the implementation of the CAP reform (S1), without income compensation, the percentage of dairy farms with negative income from farming is still largest in the group of small dairy farms and smallest in the group of large dairy farms (84.4 per cent *versus* 14.5 per cent). After income compensation, as much as 68.8 per cent of small farms and 5.5 per cent of large dairy farms have a negative income from farming. The percentage of dairy farms with a negative total household income in the small and medium size groups is substantially lower. With income compensation, 42.2 per cent of small dairy farms have a negative total farm household income as opposed to 7.3 per cent of large dairy farms. Results clearly indicate that the CAP reform affects income of small dairy farms most. However, given that small dairy farms have a relatively large non-farm income the relative change in total farm household income is smaller than the change in income from farming.

Table 2.3: Percentage of the farms in different milk quota classes with a negative income from farming under S1.

	Negative initial income from farming	Negative income from farming after CAP reform without compensation payments	Negative income from farming after CAP reform with compensation payments
Small dairy producers	14.7 (3.7)	84.4 (61.5)	68.8 (42.2)
Medium-sized dairy producers	4.6 (1.8)	35.8 (22.0)	19.3 (11.0)
Large dairy producers	1.8 (0.9)	14.5 (18.2)	5.5 (7.3)
Total	7.0 (2.1)	44.8 (33.8)	31.1 (20.1)

2.6.3 Sensitivity analysis

In our simulations, prices of variable inputs are assumed constant. Given that the demand for aggregate non-factor input and cattle increases, it is to be expected that the prices of aggregate non-factor input and cattle will also increase. How large this increase will be is difficult to predict. Here, we assume an increase of 1 per cent for both input prices.

Next we assess the sensitivity of our simulation results for these price changes. Table 2.4 shows that a price increase for aggregate non-factor input and cattle does not change demand for both inputs. This is to be expected given that both prices increase by the same percentage and the milk quota increase is still 1.5 per cent. As expected, profit decreases and the shadow price of production increases compared to S1. The increase in the shadow milk price leads to an extra reduction in the unit quota rent. Shadow prices of all quasi-fixed inputs increase compared to S1, indicating that farms would like to substitute the more expensive inputs cattle and aggregate non-factor input.

To show the effect of a relative price change of both variable inputs, we also increased the price of cattle by 1 per cent, keeping the price of the aggregate non-factor input constant. This could be realistic, given that cattle is industry-specific. As expected, the demand for cattle increases less than in S1 and the first sensitivity analysis (Table 2.4). Demand for the aggregate non-factor input increases more compared to S1 and the first sensitivity analysis. The shadow price of production increases less and profit decreases less when only the price of cattle increases. Overall, the simulation results are not extremely sensitive to the price changes, and the changes that do occur are plausible.

The last sensitivity analysis assumes that the unit quota price (and shadow price of production) is equal over farms and that the prices of variable inputs differ between farms. For the unit quota price, we took the lease price in 1999/00 and for the prices of variable inputs we calculated the shadow prices of variable inputs, using the estimated equation and the actual 1999/00 level of variable inputs. Comparison of outcomes with those of S1 shows that the differences are small. This could be expected because in S1 the average unit quota price equals the lease price and prices of variable inputs equal the shadow prices of the variable inputs for the average dairy farm.

Table 2.4: Results of sensitivity analysis: percentage changes compared to the base run.

	S1 Average	S1 and 1 per cent price increase of cattle and aggregate non-factor input	S1 and 1 per cent price increase of cattle	S1 Average shadow prices equal
Milk production	1.5	1.5	1.5	1.5
Milk price	-21.0	-21.0	-21.0	-21.0
Quantities:				
Cattle	2.3	2.3	0.9	2.1
Aggregate non-factor input	2.2	2.2	6.7	2.2
Shadow prices:				
Farm household labour	0.2	1.2	1.1	0.2
Buildings	-1.6	-0.6	-4.2	-2.0
Machinery	2.8	3.8	7.3	2.5
Land	2.0	3.0	4.4	1.9
Other output	-10.9	-10.0	1.4	-8.9
Production	0.2	1.2	1.0	0.2
Quota (unit quota rent)	-42.3	-43.3	-43.1	-42.2
Profit:				
Percentage change	-22.3	-22.4	-22.3	-22.6
€/ tonne 1999 production	-67.1	-67.4	-67.1	-67.2
€ /tonne new production†	-66.1	-66.4	-66.1	-66.2

†new production is the production of 1999/00 plus the 1.5 per cent quota increase of the 2003 CAP reform

2.7 Summary and conclusions

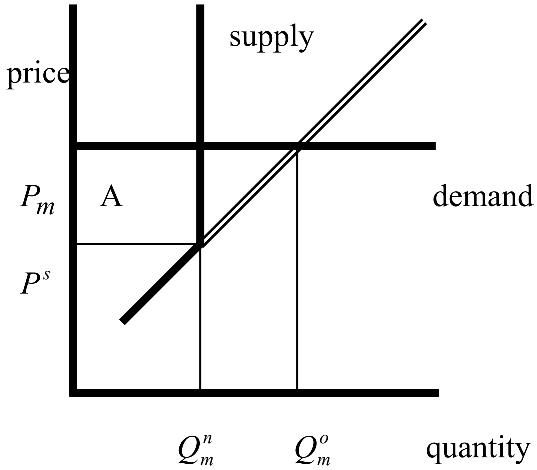
This paper reports the estimation of a production function for Dutch dairy farms under a supply quota regime, using a GMM fixed-effect panel data estimator to take account of heterogeneity among farms. This estimator can handle the mutual dependence between production and inputs (endogeneity). Endogeneity of certain input variables is not assumed *ex ante* but rather is tested for. The first-order conditions for profit maximisation are used to determine demand for variable inputs and shadow prices of quasi-fixed inputs. The model was then used to determine the economic effects for Dutch dairy farming of the CAP reform agreed in June 2003.

Profit, excluding the direct income payments, decreases on average by 22.3 per cent when we assume that the milk price falls by 21 per cent, and by 15.7 per cent when the milk price falls by 15 per cent. A direct income payment of 35.5 €/tonne compensates for 53 and 72 per cent of the profit fall respectively. Compensation is only slightly less if prices of both variable inputs increase by 1 per cent. Profit declines relatively more for small dairy farms than for large dairy farms. Even with the direct income payments (and a price decrease of 21 per cent) nearly 69 per cent of all small dairy farms will have a negative income from farming. This percentage with negative total farm household income would be 42.2 per cent. On average, these percentages are 31.1 per cent and 20.1 per cent respectively. These results show that the survival of many small dairy farms is threatened.

The results of our study are subject to some qualifications. The model used for simulation can be characterised as a comparative static short-term model, since technology, most production factors (capital, land and labour) and prices of variable inputs are assumed fixed, although we perform some sensitivity analyses here, and no explicit time path for the changes is given. In the longer term, factors and variable input prices are no longer fixed and alternative technologies may become available. In other words, we ignore structural adjustments. Moreover, it is unclear what the effect of 2003 CAP reform on the milk price will be; estimates in the Netherlands vary between 15 per cent and 21 per cent. We do not take into account farm continuation problems that might arise given the large decrease in profits. In the analysis, we did not include environmental (especially mineral) policies that could affect profit if milk production increases, since in the 2003 CAP reform this increase is small. Making the model dynamic and including environmental policies would be interesting topics for future research. The model presented here can serve as a building block in this type of extended analysis.

Appendix 2.A: Supply quota

Figure 2.A1: Supply quota



In the case of a supply quota, Q_m^n, and market price, P_m, the shadow price of production P^s gives the marginal cost of production. The unit quota rent equals P_m - P^s. When quota is freely tradable, the unit quota rent is equal to the market price of the quota. The quota rent equals the unit quota rent times the quota amount (area A in Figure 2.A1). Q_m^o would be the output level at market price P_m but without the quota system.

Appendix 2.B: Data

Table 2.B1: Data for the average specialised dairy farm in the Netherlands in 1999/00.

Variable	Unit	Mean	Standard deviation
Output:			
Milk	1000 Euro of 1999	134.08	83.65
Other output	1000 Euro of 1999	39.47	51.73
Input:			
Cattle	1000 Euro of 1999	60.31	33.23
Aggregate non-factor input	1000 Euro of 1999	88.34	60.86
Farm household labour	Hours	4068	1484
Land	Hectares	35.26	19.82
Capital buildings	1000 Euro of 1999	198.48	110.52
Capital machinery	1000 Euro of 1999	81.95	54.55
Income:			
Income from farming	1000 Euro of 1999	49.76	70.34
Total income	1000 Euro of 1999	65.14	73.05

Appendix 2.C: Parameter estimates of the production function

Table 2.C1: Estimation results and their t-ratios of the parameters of the production function.

Parameter	Estimate	t-ratio	Parameter	Estimate	t-ratio
α_1	7.922	5.25**	α_{33}	-1.277	-3.64**
α_2	2.304	1.08	α_{34}	0.342	0.79
α_3	0.453	1.38	α_{35}	-0.095	-1.16
α_4	0.401	1.53	α_{36}	2.051	2.44**
α_5	0.092	1.73*	α_{37}	0.392	1.80*
α_6	0.463	1.05	α_{38}	-1.238	-1.71*
α_7	-0.729	-6.74**	α_{44}	-0.076	-0.38
α_8	1.054	1.38	α_{45}	-0.149	-2.06*
α_{11}	-13.042	-3.12**	α_{46}	0.507	1.06
α_{12}	1.183	0.33	α_{47}	-0.137	-0.76
α_{13}	-0.362	-0.16	α_{48}	0.143	0.43
α_{14}	-0.044	-0.03	α_{55}	-0.018	-2.35**
α_{15}	0.306	1.07	α_{56}	-0.178	-2.08**
α_{16}	2.702	1.26	α_{57}	0.086	2.07**
α_{17}	4.381	4.50**	α_{58}	0.235	2.63**
α_{18}	-4.980	-2.48**	α_{66}	-1.010	-3.10**
α_{22}	-3.777	-6.07**	α_{67}	-0.214	-0.78
α_{23}	0.127	0.07	α_{68}	2.009	3.14**
α_{24}	-0.914	-2.13**	α_{77}	0.477	9.45**
α_{25}	0.630	3.21**	α_{78}	-0.761	-1.90*
α_{26}	3.169	2.35**	α_{88}	-0.087	-0.25
α_{27}	-0.462	-0.62			
α_{28}	0.541	0.61			
J-test statistic		43.03			
Degrees of freedom (*df*)		42			
Probability $\chi^2_{df} > J$		0.43			

* (**) Significant at the 10 per cent (5 per cent) significance level.

Appendix 2.D: Production elasticities, shadow prices and technical rates of substitution

Table 2.D1: Production elasticities[14] with their corresponding t-values for the estimated production function.

Variable	Value	t-ratio[15]	Variable	Value	t-ratio[a]
Cattle	0.53	15.28**	Buildings	0.01	0.50
Aggregate non-factor input	0.14	6.23**	Machinery	0.06	4.22**
Farm household labour	0.15	5.31**	Land	0.13	4.54**

** Significant at 5 per cent significance level.

Table 2.D2: Shadow prices of quasi-fixed inputs (in 1999 euros).

	Dimension	Shadow price	Boots and Peerlings (1999)[16]
Farm household Labour	Euros per hour	2.22	1.94
Land	Euros per hectare	201	704
Buildings	Euros	0.032	0.015
Machinery	Euros	0.050	0.009

Table 2.D3: Technical rates of substitution (t-ratios in brackets).

	Cattle	Aggregate non-factor input	Farm house-hold labour	Buildings	Ma-chinery	Land	Other output
Cattle	-	-4.39**	-10.55*	-162.83	-103.73	-11.65*	-91.05
		(-2.42)	(-1.89)	(-0.21)	(-1.61)	(-1.87)	(-0.24)
Aggregate non-factor input	-0.23**	-	-2.40**	-37.08	-23.62	-2.65**	-20.74
	(-5.23)		(-2.04)	(-0.36)	(-0.69)	(-2.20)	(-0.40)
Farm household labour	-0.09**	-0.09	-	-15.43	-9.83*	-1.10	-8.63
	(-4.22)	(-0.39)		(-0.22)	(-1.67)	(-1.48)	(-0.23)
Buildings	-0.01	-0.03	-0.06	-	-0.64	-0.07	-0.56
	(-0.49)	(-0.50)	(-0.49)		(-0.46)	(-0.48)	(-0.39)
Machinery	-0.01**	-0.04**	-0.10**	-1.57	-	-0.11**	-0.88
	(-3.68)	(-2.62)	(-2.71)	(-0.33)		(-2.69)	(-0.38)
Land	-0.09**	-0.38**	-0.91*	-13.98	-8.90	-	-7.82
	(-3.48)	(-2.31)	(-1.81)	(-0.21)	(-1.50)		(-0.29)
Other output	-0.01	-0.05	-0.12	-1.79	-1.14	-0.13	-
	(-0.65)	(-0.69)	(-0.66)	(-0.25)	(-0.64)	(-0.31)	

* (**) Significant at the 10 per cent (5 per cent) significance level.

[14] The production elasticities are computed as $\left(\partial f/\partial x_i\right)/\left(\bar{x}_i/\bar{q}_m\right)$ for all *i*. Here the bars indicate the average over all observations in 1999/00.

[15] The variance of elasticity ε is calculated as $S_\varepsilon = \left[\frac{\partial \boldsymbol{\varepsilon}}{\partial \boldsymbol{\theta}}\right]' \hat{\mathbf{V}} \left[\frac{\partial \boldsymbol{\varepsilon}}{\partial \boldsymbol{\theta}}\right]$, see Rao (1973: 382-389). The t-values are the estimated value divided by the square root of its variance.

[16] These results are based on a profit function approach on a different period than the period in our research.

Chapter 3 Effects of decoupled payments on labour supply of Dutch dairy farmers[1]

3.1 Introduction

The World Trade Organization (WTO) allows the use of decoupled direct income payments to support farm incomes because they are believed to have limited trade distorting effects. Decoupled payments are income transfers that are not based on actual production or input levels so that they do not alter relative prices and therefore do not attract additional resources into agriculture (USDA, 2003).

Even though decoupled payments do not change relative prices, a change in income can have an effect on labour supply. Findeis (2002) shows in a theoretical household production model that income transfers reduce total working time, caused by an increase in affordability of home time. On the other hand Hennessy (1998) shows that if farmers perceive decoupled payments to be risk free income transfers and have a decreasing relative risk aversion then the risk free income makes the farmer less risk averse about the income from farming, which increases the optimal farm production and input levels. This suggests an increase in on-farm labour (see also Goodwin and Mishra, 2005). The effects described by Findeis (2002) and Hennessy (1998) are both effects of changing income. To prevent confusion we will call the former the Findeis effect and the latter the Hennessy effect. Both effects suggest that decoupled payments may affect agricultural labour supply but how is an empirical question.

Decoupled payments were introduced in U.S. agriculture in 1996, and so there are some empirical assessments of the effects of decoupled payments on farm labour supply in the U.S. El-Osta et al. (2004) find a positive effect of decoupled payments on on-farm labour supply next to a negative effect on off-farm labour supply. This implies that the Hennessy effect is stronger than the Findeis effect for on-farm labour supply in the U.S. Decoupled payments based on historical support levels are introduced in 2006 in The Netherlands for arable farming and will be introduced in dairy farming in 2007 as a result of the 2003 Common Agricultural Policy (CAP) reform (European commission, 2003). The rights to receive decoupled payments are going to be tradable. This makes them a sort of capital investment. Therefore, we can learn how Dutch dairy farmers react to decoupled payments by looking at how they have reacted to changes in external capital income.

We use panel data collected by the LEI for the period 1987/88-1999/00. More recent data

[1] Paper by Ooms, D.L. and Hall, A.R.

are not available. The advantage of panel data over cross-section data is that it allows the empirical analysis to take unobserved heterogeneity among farms into account (e.g. Wooldridge, 2002: 251). Even though the LEI data set is extensive, it does not contain off-farm labour hours and farmer specific wage rates. Therefore, we can not estimate structural labour supply equations. The LEI data set does contain off-farm labour income. We show that it is possible to derive reduced form equations using off-farm labour income that can be used to analyze labour supply in reaction to the introduction of decoupled payments. A further complication is that off-farm labour is not supplied by every farm household. This leads to biased estimates if the sample of farms that do supply off-farm labour is not a random selection of the Dutch dairy farms population. To test for this we use the method of Semykina and Wooldridge (2005) for sample selection in panel data estimation. Based on this test we do not find evidence for sample selection bias in the off-farm labour supply equation. This means that we do not have to use an estimation method that corrects for it.

Our results indicate decoupled payments do not have an effect on either on- or off-farm labour supply. This shows that for Dutch dairy farmers the wealth effect found by Findeis (2002) is not stronger than the wealth effect found by Hennessy (1998) and vice versa. This result differs from the findings of El-Osta et al. (2004) for U.S. agriculture, who find evidence of the Hennessey wealth effect for U.S. farms. The effect of decoupled payments on off-farm labour supply we find is in correspondence with the findings of Woldehanna et al. (2000) for Dutch arable farmers who looked at the effect of non-labour income on labour supply decisions.

In the remainder of this article we give a theoretical derivation of on-and off-farm labour supply in section 3.2. In section 3.3 we derive reduced form empirical labour supply equations suitable for policy statements. In this section we show how we deal with the lack of off-farm labour hours and wages in our data set. In section 3.4 the data used are explained. In section 3.5 we explain the econometric method used to test for sample selection bias in the off-farm labour supply equation. Next to that we explain in this section the method used for estimation of the labour supply equations. In section 3.6 we report and discuss the estimation results. In section 3.7 we make policy statements based on the estimated equations. And finally, in section 3.8, we give a brief summary and conclusions.

3.2 Theoretical model

Labour supply decisions of dairy farm household i at time t are assumed to be the result of maximizing utility (u_{it}) received from consuming a vector of goods and services ($\mathbf{c}_{it}$) and home time ($h_{h,it}$) given a vector of utility shifting household characteristics ($\mathbf{z}_{u,it}$) and a vector of other variables influencing the households' decision making environment ($\mathbf{o}_{it}$),

$$u_{it} = u\left(\mathbf{c}_{it}, h_{h,it}; \mathbf{z}_{\mathbf{u},it}, \mathbf{o}_{it}\right) \tag{3.1}$$

where $u(\ )$ is a utility function that is the same for all households. Differences between the utility levels of households come from the different choices made with respect to the elements of the utility function. Total time endowment (h_{it}^0) is allocated between farm labour ($h_{f,it}$), off-farm labour ($h_{of,it}$) and home time, and so:

$$h_{it}^0 = h_{f,it} + h_{of,it} + h_{h,it}, \quad h_{of,it} \geq 0. \tag{3.2}$$

The time constraint is a strict equality because home time is defined to be the difference between total time and labour time. Home time consists of leisure, household work, etc. About half of the farmers in our data set have zero off-farm labour supply, whereas all farmers have positive on-farm labour supply and home time. Therefore we only restrict off-farm labour hours to be larger or equal to zero in this theoretical model.

Throughout, we assume all prices to be the same for all households and only different between time periods. Dairy farmers in The Netherlands produce milk ($q_{m,it}$) and other outputs ($\mathbf{q}_{\mathbf{o},it}$). For this production the farmer uses variable inputs ($\mathbf{g}_{it}$), cattle (k_{it}), farm labour and other factor inputs ($\mathbf{z}_{\mathbf{q},it}$). Since milk output is produced under a quota system it is assumed fixed on the short term. We assume farm households minimize short-term costs given the prices variable inputs ($\mathbf{v}_t$), the price of cattle ($v_{k,t}$), prices of other outputs ($\mathbf{p}_{\mathbf{o},t}$), farm labour, factor inputs and milk output. Other outputs generate revenue and are therefore seen as negative costs in the following short-term cost function $s(\cdot)$:

$$s\left(\mathbf{v}_t, v_{k,t}, \mathbf{p}_{\mathbf{o},t}, h_{f,it}, \mathbf{z}_{\mathbf{q},it}, q_{m,it}\right) =$$

$$\min_{\mathbf{g}_{it}, k_{it}, \mathbf{q}_{\mathbf{o},it}} \left\{ \mathbf{g}_{it}'\mathbf{v}_t + k_{it} v_{k,t} - \mathbf{q}_{\mathbf{o},it}'\mathbf{p}_{\mathbf{o},t} \mid h_{f,it}, \mathbf{z}_{\mathbf{q},it}, q_{m,it} \right\} \tag{3.3}$$

This cost function is assumed to be: (i) continuous and twice differentiable; (ii) non-decreasing and concave in input prices and the price of cattle (iii) non-increasing and convex in other output prices; (iv) linear homogeneous in all prices. The shadow price of farm labour $\partial s(\cdot)/\partial h_{f,it}$ is the reduction in marginal costs because of using an extra unit of farm labour in production. The reduction in costs is revenue for the farm household. The shadow price of labour is the price at which the internal market of farm labour supply clears. The formulas for the shadow prices of factor inputs and milk output are similar to that of farm labour. Since we are mainly interested in labour in this paper, we omit the explicit formulas for these other shadow prices. Farm income ($y_{f,it}$) equals milk revenue minus costs:

$$y_{f,it} = p_{m,t} q_{m,t} - \kappa\left(\mathbf{v}_t, v_{k,t}, \mathbf{p}_{\mathbf{o},t}, h_{f,it}, \mathbf{z}_{\mathbf{q},it}, q_{m,it}\right) \tag{3.4}$$

Off-farm labour income is defined as off-farm labour time multiplied by off-farm wage ($w_{of,it}$):

$$y_{of,it} = w_{of,it} h_{of,it} \tag{3.5}$$

Notice that wages are farm and time specific. The value of household consumption is defined as the product of consumption goods and services with the corresponding prices of consumption goods and services ($\mathbf{p}_{\mathbf{c},t}$). Total income consists of farm income, off-farm labour income and external capital income ($y_{o,it}$). The budget constraint of the farm household is given by:

$$y_{f,it} + y_{of,it} + y_{o,it} = \mathbf{c}_{it}'\mathbf{p}_{\mathbf{c},t} \tag{3.6}$$

Income transfers are included as part of the external capital income variable, but the EU milk price support impacts on farm income via the milk price variable. Combining equations (3.4) to (3.6) results in:

$$p_{m,t}q_{m,t} - \kappa(\mathbf{v}_t, v_{k,t}, \mathbf{p}_{\mathbf{o},t}, h_{f,it}, \mathbf{z}_{\mathbf{q},it}, q_{m,it}) + w_{of,it}h_{of,it} + y_{o,it} = \mathbf{c}_{it}'\mathbf{p}_{\mathbf{c},t} \tag{3.7}$$

We assume the household maximizes (3.1) subject to (3.2) and (3.7) by choosing the elements of the choice set $\mathbf{c}_{it}, h_{h,it}, h_{f,it}, h_{of,it}, \mathbf{g}_{it}, k_{it}, \mathbf{q}_{\mathbf{o},it}$. This results in the Lagrangian

$$\begin{aligned} &u(\mathbf{c}_{it}, h_{h,it}; \mathbf{z}_{\mathbf{u},it}, \mathbf{o}_{it}) + \lambda_1 (p_{m,t}q_{m,t} - \kappa(\mathbf{v}_t, v_{k,t}, \mathbf{p}_{\mathbf{o},t}, h_{f,it}, \mathbf{z}_{\mathbf{q},it}, q_{m,it}) \\ &+ w_{of,it}h_{of,it} + y_{o,it} - \mathbf{c}_{it}'\mathbf{p}_{\mathbf{c},t}) + \lambda_2 (h_{it}^0 - h_{f,it} - h_{of,it} - h_{h,it}) + \lambda_3 h_{of,it} \end{aligned} \tag{3.8}$$

where λ_1 is the marginal utility of income and λ_2 is the marginal utility of time. The Kuhn-Tucker first-order conditions are equation (3.2) and (3.7) plus:

$$\frac{\partial u}{\partial \mathbf{c}_{it}} = \lambda_1 \mathbf{p}_{\mathbf{c},t}, \tag{3.9}$$

$$\frac{\partial u}{\partial h_{h,it}} = \lambda_2, \tag{3.10}$$

$$\lambda_1 \frac{\partial s}{\partial h_{f,it}} - \lambda_2 = 0, \tag{3.11}$$

$$\lambda_1 w_{of,it} - \lambda_2 \leq 0, \quad h_{of,it} \geq 0, \quad h_{of,it}(\lambda_1 w_{of,it} - \lambda_2) = 0, \tag{3.12}$$

$$\frac{\partial s}{\partial \mathbf{g}_{it}} = \mathbf{0}, \tag{3.13}$$

$$\frac{\partial s}{\partial k_{it}} = \mathbf{0}, \tag{3.14}$$

$$\frac{\partial s}{\partial \mathbf{q}_{\mathbf{o},it}} = \mathbf{0} \tag{3.15}$$

If an interior solution exists (i.e. off-farm labour supply is non-zero) the first part of equation (3.12) holds as equality. In this case the first order conditions can be solved to yield:

$$\frac{\partial u(\mathbf{c}_{it}, h_{h,it}; \mathbf{z}_{\mathbf{u},it}, \mathbf{o}_{it}) / \partial \mathbf{c}_{it}}{\partial u(\mathbf{c}_{it}, h_{h,it}; \mathbf{z}_{\mathbf{u},it}, \mathbf{o}_{it}) / \partial h_{h,it}} = -\frac{\mathbf{p}_{\mathbf{c},t}}{w_{of,it}} \tag{3.16}$$

and

$$\frac{\partial s\left(\mathbf{v}_t, v_{k,t}, \mathbf{p}_{\mathbf{o},t}, h_{f,it}, \mathbf{z}_{\mathbf{q},it}, q_{m,it}\right)}{\partial h_{f,it}} = w_{of,it}. \tag{3.17}$$

If a farm household only works on the farm, the first part of equation (3.12) does not hold as equality and:

$$\frac{\partial s\left(v_t, v_{k,t}, p_{o,t}, h_{f,it}, \mathbf{z}_{\mathbf{q},it}, q_{m,it}\right)}{\partial h_{f,it}} > w_{of,it} \tag{3.18}$$

Equation (3.16) implies that the marginal rate of substitution between home time and consumption goods is equal to the ratio of the consumption good prices to the wage rate. Equation (3.17) implies that, if off-farm labour is supplied, the marginal product of farm labour is equal to off-farm wage. Equation (3.18) implies that, if no off-farm labour is supplied, the marginal product of farm labour is strictly larger than off-farm wage. The term on the left-hand side of equations (3.17) and (3.18) represents the shadow price of labour used on the farm. From equation (3.2), (3.7) and (3.9) till (3.15) we derive the reduced form functions for off-farm labour supply $l_{of}(\cdot)$ and on-farm labour supply $l_f(\cdot)$. These are functions of all variables in equation (3.1) to (3.7) except the variables in the choice set. This results in:

$$h_{of,it} = l_{of}\left(w^n_{of,it}, \mathbf{p}^{\mathbf{n}}_{\mathbf{c},t}, p^n_{m,t}, v^n_{k,t}, q_{m,it}, \mathbf{p}^{\mathbf{n}}_{\mathbf{o},t}, y^n_{o,it}, \mathbf{z}_{\mathbf{u},it}, \mathbf{z}_{\mathbf{q},it}, \mathbf{o}_{it}, h^0_{it}\right), \tag{3.19}$$

$$h_{f,it} = l_f\left(w^n_{of,it}, \mathbf{p}^{\mathbf{n}}_{\mathbf{c},t}, p^n_{m,t}, v^n_{k,t}, q_{m,it}, \mathbf{p}^{\mathbf{n}}_{\mathbf{o},t}, y^n_{o,it}, \mathbf{z}_{\mathbf{u},it}, \mathbf{z}_{\mathbf{q},it}, \mathbf{o}_{it}, h^0_{it}\right). \tag{3.20}$$

where the superscript n indicates that the corresponding variable is normalized by the price index of a composite of variable inputs. This is done to impose homogeneity of degree zero in prices and income. Equations (3.19) and (3.20) express on- and off-farm labour supply as a function of, amongst others, external labour supply. In this research we want to use revealed behaviour with respect to changing external capital income to make statements about possible effects of the introduction of decoupled payments. To this end we need functional forms to make equations (3.19) and (3.20) operational.

3.3 Empirical model

Equation (3.19) and (3.20) show that labour supply is expressed in time units and is, amongst others, explained by individual off-farm wages. The data set of Dutch dairy farmers at our disposal contains on-farm hours. However, it does not contain off-farm hours and individual off-farm wages. In this section we explain how we deal with these data challenges in deriving empirical models for on- and off-farm labour supply that can be used to make statements about expected labour supply behaviour with respect to decoupled payments. First we discuss the empirical model for off-farm labour supply. To this end, we assume that (3.19) has the following functional form:

$$\ln\left(h_{of,it}\right) = \beta_i + \beta_w \ln\left(w_{of,it}\right) + \mathbf{x}_{-\mathbf{w},it}{'}\boldsymbol{\beta}_{-\mathbf{w}} + \varepsilon_{it} \tag{3.21}$$

where $\mathbf{x}_{-\mathbf{w},it}$ is the vector of all explanatory variables except off-farm wage, ε_{it} is an error term with expectation zero, β_i is a farm specific effect, β_w is the parameter associated with the log of wage and the column vector $\boldsymbol{\beta}_{-\mathbf{w}}$ contains parameters associated with the other explanatory variables. For notational convenience, the content of $\mathbf{x}_{-\mathbf{w},it}$ is not specified for this part of the discussion.

Instead of off-farm hours, our data set contains off-farm income. The definition of off-farm income is $y_{of,it} \equiv h_{of,it} w_{of,it}$. This can be written in logarithmic form as:

$$\ln\left(y_{of,it}\right) \equiv \ln\left(h_{of,it}\right) + \ln\left(w_{of,it}\right) \tag{3.22}$$

Instead of farmer specific off-farm wages, our data set contains national wages for labourers in the agricultural sector (w_t). Data on these wages differ between periods, not between farms. Using this national wage rate for individual farmers implies a measurement error (ζ_{it}). We assume that $w_{of,it} = w_t \zeta_{it}$ with $\zeta_{it} > 0$. Inserting this together with (3.22) into (3.3) gives:

$$\ln\left(y_{of,it}\right) = \beta_i + \breve{\beta}_w \ln\left(w_t\right) + \breve{\beta}_w \ln\left(\zeta_{it}\right) + \mathbf{x}_{-\mathbf{w},it}{'}\boldsymbol{\beta}_{-\mathbf{w}} + \varepsilon_{it}\,. \tag{3.23}$$

We assume that the measurement error in the wage variable is correlated with education level and age, however also with off-farm wage. This results in a biased estimate of $\breve{\beta}_w$ and therefore of β_w. The effect of wage on labour supply is one of the most important effects in labour supply literature. To avoid confusion by presenting a biased estimate, we replace $\ln(w_t)$ by the time dummies β_t resulting in:

$$\ln\left(y_{of,it}\right) = \beta_i + \beta_t + \breve{\beta}_w \ln\left(\zeta_{it}\right) + \mathbf{x}_{-\mathbf{w},it}'\boldsymbol{\beta}_{-\mathbf{w}} + \varepsilon_{it} \,. \tag{3.24}$$

The time dummies not only represent the effect of the logarithm of the off-farm wage index, but also autonomous changes over years and other variables that do not vary between farms, such as the other price variables in equation (3.19) and (3.20).

We divide the vector of explanatory variables $\mathbf{x}_{-\mathbf{w},it}$ into: (i) a vector $\mathbf{x}_{\mathbf{r},it}$ containing variables that are correlated with the measurement error and that vary between farms, with corresponding parameter vector $\boldsymbol{\beta}_{\mathbf{r}}$ and (ii) a vector of explanatory variables $\mathbf{x}_{\mathbf{b},it}$ with corresponding parameter vector $\boldsymbol{\beta}_{\mathbf{b}}$. $\mathbf{x}_{\mathbf{r},it}$ contains education level, age and age squared. The vector $\mathbf{x}_{\mathbf{b},it}$ contains a constant, the level of milk production, land, buildings, machinery, social benefits, number of household members, presence of a successor and external capital income. We assume that $\ln\left(\zeta_{it}\right) = \mathbf{x}_{\mathbf{r},it}'\boldsymbol{\alpha} + \mu_{it}$ gives the relation between the measurement error and $\mathbf{x}_{\mathbf{r},it}$ where $\boldsymbol{\alpha}$ is a parameter vector and μ_{it} has a conditional expectation of zero given $\mathbf{x}_{\mathbf{b},it}$. Inserting this into (3.24) gives:

$$\ln\left(y_{ofit}\right) = \beta_i + \beta_t + \mathbf{x}_{\mathbf{b},it}'\boldsymbol{\beta}_{\mathbf{b}} + \mathbf{x}_{\mathbf{r},it}'\left(\breve{\beta}_w\boldsymbol{\alpha} + \boldsymbol{\beta}_{\mathbf{r}}\right) + \tau_{it} \tag{3.25}$$

where $\tau_{it} \equiv \breve{\beta}_w \mu_{it} + \varepsilon_{it}$.

The key elements in the policy simulation are the milk price, milk output and external income. Milk output and external income are contained in $\mathbf{x}_{\mathbf{b},it}$, because they are assumed to be uncorrelated with the measurement error in the off-farm wage variable. The effect of milk price on labour supply can not be directly estimated using (3.25). The effect of a changing milk price is captured by the time dummies, but can not be distinguished from other variables that do not vary between farms. Labour supply can change due to a change in the off-farm wage or shadow price of on-farm labour, resulting in a substitution effect between on- and off-farm labour, or by a change in income resulting in an income effect. From the theoretical model in the previous section follows that milk price does not influence the shadow price of on-farm labour under a milk quota regime. Therefore, a change in milk price will not cause a substitution effect. As a result, the change in milk price can only cause an income effect on labour supply. The effect of a change in income is measured by the parameter associated with the external income variable. This measure can also be used to assess the effect of an income change due to a change in milk price. Therefore, an estimated version of (3.25) can form a basis for policy simulations on the impact of decoupled payments within the 2003 CAP reform.

From (3.20) it follows that off-farm wage is also an explanatory variable in the on-farm labour supply function. Therefore, in this function we also have to deal with the fact that we do not have data on farmer specific off-farm wages. To this end we choose the functional form in (3.20) comparable to the functional form of (3.19) given in equation (3.21):

$$\ln\left(h_{f,it}\right) = \gamma_i + \gamma_w \ln\left(w_{of,it}\right) + \mathbf{x}_{-\mathbf{w},it}'\boldsymbol{\gamma}_{-\mathbf{w}} + \nu_{it} \qquad (3.26)$$

where ν_{it} is an error term with conditional expectation zero given $\mathbf{x}_{-\mathbf{w},it}$. γ_i is a farm specific effect, γ_w is the parameter associated with the log of wage and the column vector $\boldsymbol{\gamma}_{-\mathbf{w}}$ contains parameters associated with the other explanatory variables. Following the same reasoning that leads to (3.25), (3.26) turns into:

$$\ln\left(h_{f,it}\right) = \gamma_i + \gamma_t + \mathbf{x}_{\mathbf{b},it}'\boldsymbol{\gamma}_{\mathbf{b}} + \mathbf{x}_{\mathbf{r},it}'\left(\gamma_w\boldsymbol{\alpha} + \boldsymbol{\gamma}_{\mathbf{r}}\right) + \omega_{it} \qquad (3.27)$$

where $\omega_{it} \equiv \gamma_w\mu_{it} + \nu_{it}$ and $\boldsymbol{\gamma}_{\mathbf{r}}$ is the parameter vector associated with $\mathbf{x}_{\mathbf{r},it}$ in the off-farm labour supply equation and $\boldsymbol{\gamma}_{\mathbf{b}}$ is the parameter vector associated with $\mathbf{x}_{\mathbf{b},it}$ in the off-farm labour supply equation and. Similar to the off-farm labour supply equation the parameter estimates of variables in $\mathbf{x}_{\mathbf{r},it}$ are biased through the term $\gamma_w\boldsymbol{\alpha}$. However, the parameter estimates of the policy variables are not biased by the measurement error. Therefore, estimating equation (3.26) leads to a suitable model for policy simulation, even though it does not lead to a correct on-farm labour supply equation.

3.4 Data

The farm specific data come from the LEI unbalanced rotating panel data set of Dutch farms. A farm is classified to be a dairy farm if its returns consist for 50 per cent or more of milk revenues. The data set consists of 6338 observations on 1307 farms. The period investigated is from 1987/88 until 1999/00. Off-farm labour is represented by off-farm labour income. The total number of family hours worked on the farm represents on-farm labour. Off-farm wage is represented by the national index of wages for agricultural hired labour. 1991 is the base year for this and subsequent indices. The price variable used to impose linear homogeneity in income and prices a Thornqvist price index for variable input. Variable input contains, amongst others, feed and veterinary costs. External non-labour income is a monetary value. It includes, amongst others, income from renting out houses and income from financial capital invested in bonds and shares. Social benefits is a monetary value as well. It contains social benefits for elderly, children and disabilities. Land is expressed in the number of hectares used by the farmer. The implicit quantities of buildings, machinery and milk output are obtained by dividing the total values of these variables, as obtained from the aforementioned data set, by their corresponding price index. For buildings and machinery the Tornqvist price index is used. For milk output this is done to keep the quality differences (mainly differences in percentage fat) between different types of milk into account. Household variables used are the number of household members, a dummy for the presence of a successor and a discrete variable indicating the education level of the head of the household. Debt is the total value of short and long-term debt. Assets is the total value of all the belongings of the farm and is calculated by the LEI. The rental value of houses owned by the farm is a monetary value. In Table 3.A1 in Appendix 3.A an overview of the units, mean and standard deviation of the variables used is given.

3.5 Estimation

In this section we describe the estimation method used for the on- and off-farm labour supply equations. Not all farmers in The Netherlands supply off-farm labour. If the group of farmers that do supply off-farm labour is not a representative sample of all farmers, a sample selection estimation approach is needed. To test for sample selection we use the test for sample selection bias in panel data models proposed by Semykina and Wooldridge (2005). This test is described in Appendix 3.B. Based on this test we find no evidence that the sample is not representative of all Dutch dairy farmers. We conclude that there is an absence of sample selection. Therefore we can use a linear panel data estimation method for both the on- and off-farm labour supply equation. For on-farm labour supply it is convenient to rewrite (3.27) as:

$$\ln\left(h_{f,it}\right) = \mathbf{x}_{1,it}'\boldsymbol{\theta}_1 + \mathbf{x}_{2,i}'\boldsymbol{\theta}_2 + a_i + \nu_{it} \qquad (3.28)$$

where $\mathbf{x}_{1,it}$ is a vector of observable explanatory variables that vary both over farms and time with corresponding vector of unobservable parameters $\boldsymbol{\theta}_1$, $\mathbf{x}_{2,i}$ is a vector of observable explanatory variables that vary over farms but are constant over time with corresponding vector of unobservable parameters $\boldsymbol{\theta}_2$, a_i is an unobservable farm specific effect and ν_{it} is an unobservable error term. Estimation of this equation is complicated by the unobservable farm specific effect, a_i. Moreover, $\mathbf{x}_{1,it}$ contains external capital income, which we assume to be endogenous in both the on- and off-farm labour supply equation. To allow for the endogeneity of external capital income in $\mathbf{x}_{1,it}$, we construct a vector of strictly exogenous variables $\mathbf{z}_{1,it}$, containing the exogenous variables in $\mathbf{x}_{1,it}$ and instruments to allow for the endogeneity of external capital income. In this article, we follow an instrumental variable approach of the estimator proposed by Mundlak (1978) in which a_i is replaced by a linear combination of a constant term and the individual means of the variables in $\mathbf{z}_{1,it}$. This results in:

$$\ln\left(h_{fit}\right) = \theta_0 + \mathbf{x}_{1,it}'\boldsymbol{\theta}_1 + \mathbf{x}_{2,i}'\boldsymbol{\theta}_2 + \overline{\mathbf{z}}_{1,i}'\boldsymbol{\rho} + u_{it} \qquad (3.29)$$

where θ_0 is a constant term, $\boldsymbol{\rho}$ is a parameter vector to be estimated, $\overline{\mathbf{z}}_{1,i} = T_i^{-1}\sum_{t=1}^{T_i}\mathbf{z}_{1,it}$ and u_{it} is an error term that is the sum of ν_{it} and the error term of the linear projection of the farm specific effect a_i on a constant term and $\overline{\mathbf{z}}_{1,i}$. The Mundlak (1978) estimator allows for arbitrary correlation between a_i and $\overline{\mathbf{z}}_{1,i}$ and is a special case of the Chamberlain (1982) estimator. Wooldridge (2002: 325) states that without making strong assumptions on the relationship between a_i and $\overline{\mathbf{z}}_{1,i}$ an efficient estimator for the Chamberlain (1982) model is obtained by applying a pooled version of the Generalized Method of Moments (GMM) to the estimation equation. Therefore, the parameter vectors in (3.29) are estimated by pooled GMM. This estimation is based on the moment conditions

$$E[u_{it}\mathbf{z}_{it}] = \mathbf{0} \tag{3.30}$$

for all i and t for which data are available. $\mathbf{z}_{it} = (1, \mathbf{z}_{1,it}', \mathbf{x}_{2,i}', \overline{\mathbf{z}}_{1,i}')'$ and E is the expectation operator. The GMM estimator used to estimate the vector of unknown variables, $\boldsymbol{\theta} = (\nu_{it}, \boldsymbol{\theta}_1', \boldsymbol{\theta}_2', \boldsymbol{\rho}')'$, is

$$\hat{\boldsymbol{\theta}} = \mathbf{Q}^{-1}\left(\sum_{i=1}^{N}\mathbf{x}_i'\mathbf{z}_i\right)\left(\sum_{i=1}^{N}\mathbf{z}_i'\hat{\mathbf{u}}_i\,\hat{\mathbf{u}}_i'\mathbf{z}_i\right)^{-1}\left(\sum_{i=1}^{N}\mathbf{z}_i'\mathbf{h}_{fi}\right) \tag{3.31}$$

where N is the number of farms in the data set, $\mathbf{x}_i = (\mathbf{x}_{i1},...,\mathbf{x}_{iT})'$, T is the total number of time periods in the data set, $\mathbf{x}_{ht} = (1, \mathbf{x}_{1,it}', \mathbf{x}_{2,i}'\overline{\mathbf{z}}_{1,i}')'$ is a p × 1 vector of explanatory variables, $\mathbf{z}_i = (\mathbf{z}_{i1},...,\mathbf{z}_{iT})'$, $\mathbf{h}_{fi} = (\ln(h_{fi1}),...,\ln(h_{fiT}))'$, $\mathbf{u}_i = (u_{i1},...,u_{iT})'$,

$$\mathbf{Q} = \left(\sum_{i=1}^{N}\mathbf{x}_i'\mathbf{z}_i\right)\left(\sum_{i=1}^{N}\mathbf{z}_i'\hat{\mathbf{u}}_i\,\hat{\mathbf{u}}_i'\mathbf{z}_i\right)^{-1}\left(\sum_{i=1}^{N}\mathbf{z}_i'\mathbf{x}_i\right) \tag{3.32}$$

and $\hat{\mathbf{u}}_i$ is created with a first step estimator of $\boldsymbol{\theta}$ using equations (3.31) and (3.32) without the term $\hat{\mathbf{u}}_i\,\hat{\mathbf{u}}_i'$. The approximate large sample variance for the estimator is:

$$\mathbf{V} = \mathbf{Q}^{-1} \tag{3.33}$$

In this research we have an unbalanced data set. If there is no observation for farm i at time t, its corresponding variables are zero in the equations above. To see whether the initial structure of the model is correct, we use Sargan's J-test of overidentifying restrictions (Hall, 2005: 47). If there are q moment conditions[2] and p parameters, there are q - p overidentifying restrictions. In Sargan's J-test:

$$J = \left(\sum_{i=1}^{N}\hat{\mathbf{u}}_i'\mathbf{z}_i\right)\left(\sum_{i=1}^{N}\mathbf{z}_i'\hat{\mathbf{u}}_i\,\hat{\mathbf{u}}_i'\mathbf{z}_i\right)^{-1}\left(\sum_{i=1}^{N}\mathbf{z}_i'\hat{\mathbf{u}}_i\right) \tag{3.34}$$

[2] This means that there are q instruments.

where $\hat{\mathbf{u}}_i$ is the vector of residuals created with $\hat{\boldsymbol{\theta}}$ of equation (3.31). The null hypothesis of this test is that the over-identifying restrictions hold, and hence that the initial structure of the model is correct. The test statistic has a χ^2_{q-p} distribution under the null-hypothesis.

The log of off-farm labour income, $\ln(y_{ofit})$, is assumed to be explained by the same variables as $\ln(h_{fit})$ and, therefore, to be generated by

$$\ln(y_{ofit}) = \mathbf{x}_{1,it}'\boldsymbol{\beta}_1 + \mathbf{x}_{2,i}'\boldsymbol{\beta}_2 + c_i + \upsilon_{it} \qquad (3.35)$$

where $\boldsymbol{\beta}_1$ and $\boldsymbol{\beta}_2$ are vectors of unobservable parameters, c_i is an unobservable farm specific effect and υ_{it} is an unobservable error term. As in the on-farm labour supply equation, the farm specific effect is replaced by a linear combination of a constant term and $\bar{\mathbf{z}}_{1,i}$. This results in:

$$\ln(y_{ofit}) = \beta_0 + \mathbf{x}_{1,it}'\boldsymbol{\beta}_1 + \mathbf{x}_{2,i}'\boldsymbol{\beta}_2 + \bar{\mathbf{z}}_{1,i}'\boldsymbol{\kappa} + e_{it} \qquad (3.36)$$

,where β_0 is a constant term, $\boldsymbol{\kappa}$ is a parameter vector to be estimated and e_{it} is an error term that is the sum of υ_{it} and the error term of the linear projection of the farm specific effect c_i on a constant term and $\bar{\mathbf{z}}_{1,i}$. Estimation of the parameters in (3.36) is similar to the estimation of the parameters in (3.29) explained above. For this reason we do not provide the equations for the estimation of the off-farm labour supply equation.

3.6 Estimation results

From the previous section it follows that all test and estimation approaches are based on instrumental variable estimation. In all estimations performed we allow external capital income to be endogenous. A source of external capital income is renting out houses. We use the rental value of houses as an instrument, since we believe this can not be changed by the farmer in the short term. In principle one instrument is sufficient to correct for the possible endogeneity of external capital income. However, using more instruments gives the opportunity to test the validity of the instruments as described in the estimation section above.

Therefore we use debt over asset ratio as an instrument as well. $\mathbf{z}_{\mathbf{1},it}$ now contains the two instruments used to allow for the endogeneity for external capital income described above and all exogenous time-varying variables in the on- and off-farm labour supply equations: milk output; land; buildings; machinery; social benefits; age; age squared and the time dummies for 1988 to 1999. The time dummy for 1987 is not included to circumvent the dummy variable trap (Greene, 1993: 381). $\mathbf{x}_{\mathbf{1},it}$ also contains all exogenous time-varying variables and external capital income. $\mathbf{x}_{\mathbf{2},i}$ contains the exogenous time-invariant variables; number of household members; successor dummy

First we perform the test for sample selection bias of Semykina and Wooldridge (2005), described in Appendix 3.B, for the off-farm labour supply equation. The model used for this test has a J-test statistic of 0.57, which does not exceed the 10 per cent critical value of the χ_1^2 distribution (2.71). Therefore, the model is not rejected. This confirms the validity of the instruments used as well as the exogeneity of the other variables in this model. The t-ratio for the estimated η in equation (3.B.3) is 0.92 and, hence, not significantly different from zero at the 10 per cent level. This indicates no sample selection bias and we can use the Mundlak (1978) estimation procedure for both the on- and off-farm labour supply equations.

The on- and off-farm labour supply equations have J-test statistics of 0.10 and 0.58, respectively. These, do not exceed the 10 per cent critical value of the χ_1^2 distribution (2.71). Therefore, both models are not rejected. This confirms the validity of the instruments used as well as the exogeneity of the other variables in these models.

Table 3.1 gives the estimation results for the off- and on-farm labour supply equations. From the derivation of the empirical model follows that the parameter estimates for education level, age and age squared are biased and so it is impossible to interpret them meaningfully. Next to that, it is argued that the time dummies take different effects that do not vary between farms into account. Therefore, these do not have an economic interpretation.

External capital income does not have a significant effect on either on- and off-farm labour. This implies that we do not find evidence for an income effect on farm labour supply. We do find a negative effect of social benefits on on-farm labour supply. Social benefits are benefits for elderly, disabled and children. These all imply limited labour supply possibilities. Therefore, the found effect is more likely to be the effect of limited supply possibilities then of an income effect.

Table 3.1. Estimation Results for Labour Supply Equations

Dependent variable:	Log off-farm labour		Log on-farm labour	
Unbiased estimates:	Est.	t-ratio	Est.	t-ratio
Constant	8.66	5.11**	7.78	41.31**
External capital income	1.12	0.87	-0.07	-0.53
Social benefits	-0.08	-0.11	-0.23	-2.80**
Milk output	-2.14	-1.80*	0.26	2.25**
Land	1.12	1.23	0.17	2.02**
Buildings	-1.10	-2.33**	-0.02	-0.41
Machinery	-0.09	-0.01	0.01	0.00
Household members	-0.03	-0.81	0.03	8.71**
Successor dummy	0.34	2.48**	0.18	11.57**
Biased estimates:				
Age	1.59	0.28	-0.19	-0.33
Age^2	-2.24	-0.41	0.13	0.24
Education	-0.09	-0.84	-0.02	-1.25
Time dummies:				
1988 dummy	-0.17	-1.50	-0.00	-0.73
1989 dummy	0.19	1.40	-0.01	-1.76*
1990 dummy	0.25	1.59	-0.04	-3.25**
1991 dummy	0.20	1.13	-0.05	-3.91**
1992 dummy	0.52	2.73**	-0.06	-4.15**
1993 dummy	0.39	1.91*	-0.08	-5.41**
1994 dummy	0.60	2.95**	-0.09	-5.68**
1995 dummy	0.77	3.39**	-0.10	-5.74**
1996 dummy	0.85	3.49**	-0.11	-5.34**
1997 dummy	0.99	3.88**	-0.13	-5.56**
1998 dummy	0.84	3.37**	-0.13	-5.55**
1999 dummy	1.14	4.22**	-0.14	-5.48**
J-test statistic		0.10		0.58
Degrees of freedom (*df*)		1		1
Probability $\chi^2_{df} > J$		0.75		0.45

*(**) Significant at the 10 per cent (5 per cent) significance level.
Note: Parameter estimates for variables that are (not) correlated with individual off-farm wage rate are (un)biased. See the derivation of the empirical model in section 3.3.

The parameters for milk output are significant and have expected signs based on a substitution effect. However, the economic significance of the effect of a change in milk output on on-farm labour supply is, with an elasticity of 0.08 for the average farmer, negligible. The elasticity of off-farm labour with respect to milk output for the average farmer is -0.69, though. One has to keep in mind that off-farm labour supply is limited for Dutch dairy farmers. Dividing off-farm labour income by the average wage rate for hired agricultural labour results in a number of hours that is on average 12 per cent of average hours supplied on-farm. So in the case of substitution of labour, the percentage change for off-farm labour is per definition higher than for on-farm labour. Next to that, changes in off-farm labour supply are often not just by one hour per week, but most of the time more. In percentage terms, this change is large given the low amount of off-farm labour supplied.

Land has a significant effect on on-farm labour supply at the 10 per cent level. This is an expected result. As with milk output, the economic significance of a change in land is, with an elasticity of 0.06 for the average farmer, negligible. It is therefore not surprising that the effect of land on off-farm labour is not even significant. Buildings have a significantly negative effect on off-farm labour supply. This result is similar to the result of Woldehanna et al. (2000) for the effect of land on off-farm labour supply of Dutch arable farmers. They show that this effect is caused by a positive effect of the factor input on farm profit, which makes off-farm labour relatively less profitable. In line with this reasoning a positive effect of buildings on on-farm labour supply is expected. This effect is not found. This might be caused by a substitution effect between buildings and labour, which cancels the effect of the relative profitability increase of on-farm labour out. Machinery does not have a significant impact on labour supply. This means that we can not declare labour to be either a substitute or a complement to machinery. The number of household members only has a significant effect on on-farm labour supply. This reflects farmers' work ethic in which household members are expected to contribute to the activities on the farm. Apparently, this expectation does not hold for off-farm labour activities. The successor dummy is significantly positive for both on- and off-farm labour. If a farm has a successor, the farm family might be inclined to put extra effort in the farm to ensure the future of the farm. For a successor to actually take over the farm, a lot of money is needed and next to that most Dutch dairy farms do not earn enough for two families. Therefore, the successor often works off-farm for a while, explaining the positive effect of a successor on off-farm labour supply. Overall, most parameters estimated have expected signs. Furthermore, it shows that time invariant variables are important for explaining labour supply.

3.7 Policy

The CAP reform of the EU entails: (i) a phased reduction in intervention prices for skimmed milk powder of 15 per cent and 25 per cent for butter; (ii) a phased milk quota increase of 1.5 per cent; (iii) a phased introduction of decoupled direct income payment of €35.50 per ton. The reduction of the intervention prices is assumed to reduce the milk price farmers receive. The quota increase is expected to increase milk production by the same percentage (Ooms and Peerlings, 2005). Milk output and external capital income are explanatory variables in our estimated models. In the empirical model section we explain that a change in milk price can only have an income effect on labour supply under a milk quota regime. The income effect on labour is estimated using the external capital income variable. Hereby, we do not find evidence for an income effect on labour supply.

Quota increase has a small positive effect on on-farm labour supply and a negative effect on off-farm labour supply. Using the estimated labour supply models, we simulate the effect of the 1.5 per cent quota increase for each farmer in our data set in 1999/00. In simulation we keep all other variables at their 1999/00 level. Even though, we calculate for each individual farm in the sample the policy effects, we only present average changes here. On-farm labour increases 0.15 per cent and off-farm labour decreases 1.14 per cent. One has to take into account that the results are presented in percentage change and that off-farm labour supplying dairy farmers supply more on-farm than off-farm labour. Calculations based on our data set suggest that on average on-farm labour supply is about 12 per cent of total labour supply for off-farm labour supplying farms. Even though the changes are small, this implies that total labour supply remains approximately the same, while off-farm labour is substituted for on-farm labour. The latter is caused by the fact that the increase of milk production demands a small increase of on-farm labour.

Now we turn to the main topic of this article: decoupled payments. Decoupled payments change external capital income. We do not find an effect of external capital income on labour supply of Dutch dairy farmers. Therefore, we conclude that decoupled payments do not influence labour supply of Dutch dairy farmers. For on-farm labour Findeis (2002) predicts a decrease as a result of decoupled payments, whereas Hennessy (1998) predicts under certain conditions an increasing demand for farm inputs as a result of decoupled payments. Our results imply that the Hennessy effect is not larger than the Findeis effect and vice versa for on-farm labour supply of Dutch dairy farmers. El-Osta et al. (2004) and Goodwin and Mishra (2004) find a statistically significant, but economically insignificant negative effect of decoupled payments on off-farm labour supply. In contrast, we do not find a statistically significant effect. This is in line with the findings of Woldehanna et al. (2000) for Dutch arable farmers.

3.8 Summary and conclusions

The purpose of this article is to determine the effect on on-farm and off-farm labour of decoupled payments as part of the 2003 CAP reform. To this end we estimate reduced form on-farm and off-farm labour supply equation for Dutch dairy farmers using panel data estimation techniques and taking possible sample selection in the off-farm labour supply equation into account. All Dutch dairy farmers supply labour to their farm. We use the linear panel data estimation approach of Mundlak (1978) for estimation of the on-farm labour supply equation. About half of Dutch dairy farmers supplies labour off-farm. The test proposed by Semykina and Wooldridge (2005) leads to the conclusion that we can not reject the hypothesis that the farms supplying off-farm labour are a representative sample from the Dutch dairy farms' population. Therefore, we can use the linear panel data estimation approach of Mundlak (1978) for estimation of the off-farm labour supply equation as well. The estimated equations are used to make statements about the 2003 CAP reform. Part of these changes is the introduction of decoupled payments.

Decoupled payments are advocated by the World Trade Organization (WTO) as a way to transfer income to farmers with minimal potential to distort production and trade. However, theoretically decoupled payments can have impact on production through an income effect changing on and off farm labour supply (USDA). However, we do not find such an effect of decoupled payments on both on- and off-farm labour supplies and therefore production.

The results of our study are obviously subject to some qualifications. The model used for simulation can be characterized as a comparative static short-term model, since technology, most production factors (capital and land) and prices of variable inputs are assumed fixed and no explicit time path for the changes is given. In the longer term, factors and variable input prices are no longer fixed and alternative technologies may come available. Moreover, it is unclear what the exact effect of 2003 CAP reform on the milk price will be. We do not take into account farm continuation problems that might arise given the large decrease in profits. Making the model dynamic is an interesting topic for future research. The model presented here can serve as a building block in this type of extended analysis.

Appendix 3.A: Data

Table 3.A1: Data for Average Specialized Dairy Farm in the Netherlands in 1999/00

Variable	Unit	Mean	Standard deviation
Off-farm labour income[a]	1000 Euro	5.09	7.77
On-farm labour	Hours	4068	1484
External capital income	1000 Euro	7.76	7.42
Social Benefits	1000 Euro	2.53	3.17
Milk output	1000 Euro of 1999	134.08	83.65
Land	Hectares	35.26	19.82
Buildings	1000 Euro of 1999	198.48	110.52
Machinery	1000 Euro of 1999	81.95	54.55
Debt	per cent of Assets	27.45	18.02
Household members	Number	4.65	1.91
Successor	Percentage	41.67	
Education	Discrete variable	2.45	0.60
Input price index	1991 = 1	0.92	
Rental value of houses	1000 Euro of 1999	4.73	3.26

[a] Off-farm labour income is positive for 46.2 per cent of observations.

Appendix 3.B: Testing for sample selection in the off-farm labour supply model

Off-farm labour is only observed for those households that choose to supply it. We therefore introduce an indicator variable d_{it} that takes the value one if household *i* supplies off-farm labour in period *t*. The variables explaining the binary choice on off-farm labour, in this estimation procedure, should be strictly exogenous with respect to the error term in the off-farm labour supply equation. We assume the strictly exogenous variables in the on-farm labour supply equation to be strictly exogenous in the off-farm labour supply equation as well. This results in the binary off-farm labour supply choice function

$$d_{it} = I\{\mathbf{z}_{1,it}'\boldsymbol{\psi}_1 + \mathbf{x}_{2i}'\boldsymbol{\psi}_2 + b_i - u_{it} \geq 0\} \tag{3.B.1}$$

where $I\{\cdot\}$ is an indicator function that takes the value one if the event in the curly brackets occurs but is zero otherwise, $\boldsymbol{\psi}_1$ and $\boldsymbol{\psi}_2$ are vectors of unobservable parameters, b_i is an unobservable farm specific effect, and u_{it} is an unobservable error term. If $d_{it} = 1$ and so off-farm labour is supplied then the log of off-farm labour supply, $\ln(y_{ofit})$, is assumed to be explained by:

$$\ln(y_{ofit}) = \mathbf{x}_{1,it}'\boldsymbol{\beta}_1 + \mathbf{x}_{2,i}'\boldsymbol{\beta}_2 + c_i + v_{it} \tag{3.B.2}$$

where $\boldsymbol{\beta}_1$ and $\boldsymbol{\beta}_2$ are vectors of unobservable parameters, c_i is an unobservable farm specific effect and v_{it} is an unobservable error term.

Two problems arise in the estimation of equation (3.B.2). First, the individual effect, c_i, is unobserved. Second, there is a potential sample selection bias if the selection equation, equation (3.B.1), does not select a random sample from the underlying population.

Semykina and Wooldridge (2005) model c_i as an explicit function of the explanatory variables in the fashion proposed by Mundlak (1978) and Chamberlain (1982). A test for sample selection bias is performed by including the inverse Mill's ratio as an additional regressor in the off-farm labour supply equation in the spirit of Heckman (1979).

In both equations, the individual effect is replaced by a linear combination of a constant term and the individual means of strictly exogenous time varying variables. The selection equation becomes $d_{it} = I\{\psi_0 + \mathbf{z}_{1,it}'\boldsymbol{\psi}_1 + \mathbf{x}_{2i}\boldsymbol{\psi}_2 + \overline{\mathbf{z}}_{1,i}'\boldsymbol{\pi} - u_{it} \geq 0\}$ where $\boldsymbol{\pi}$ a vector of unobservable parameters is. Assuming that off-farm labour is supplied $(d_{it}=1)$, the off-farm labour supply equation can be written as

$$\ln(y_{ofit}) = \beta_0 + \mathbf{x}_{1,it}'\boldsymbol{\beta}_1 + \mathbf{x}_{2,i}'\boldsymbol{\beta}_2 + \bar{\mathbf{z}}_{1,i}'\boldsymbol{\kappa} + \eta\lambda_{it}(\boldsymbol{\psi},\boldsymbol{\pi}) + e_{it} \qquad (3.B.3)$$

where $\boldsymbol{\psi} = (\psi_0, \boldsymbol{\psi}_1', \boldsymbol{\psi}_2')'$, $\boldsymbol{\kappa}$ is a vector of unobservable parameters, and

$$\lambda_{it}(\boldsymbol{\psi},\boldsymbol{\pi}) = \frac{\phi(\psi_0 + \mathbf{z}_{1,it}'\boldsymbol{\psi}_1 + \mathbf{x}_{2i}\boldsymbol{\psi}_2 + \bar{\mathbf{z}}_{1,i}'\boldsymbol{\pi})}{\Phi(\psi_0 + \mathbf{z}_{1,it}'\boldsymbol{\psi}_1 + \mathbf{x}_{2i}\boldsymbol{\psi}_2 + \bar{\mathbf{z}}_{1,i}'\boldsymbol{\pi})}. \qquad (3.B.4)$$

Under the assumption that u_{it}, v_{it} are jointly normally distributed conditional on $\{\mathbf{x}_{1,it}, \mathbf{x}_{2,i}, \mathbf{z}_{1,it}, \bar{\mathbf{x}}_{1,i}, \bar{\mathbf{z}}_{1,i}\}$, the error term e_{it} satisfies $E[e_{it} \mid \mathbf{x}_{1,it}, \mathbf{x}_{2,i}, \mathbf{z}_{1,it}, \bar{\mathbf{x}}_{1,i}, \bar{\mathbf{z}}_{1,i}] = 0$. Therefore, if $\boldsymbol{\psi}$ and $\boldsymbol{\pi}$ were known (and so $\lambda_{it}(\boldsymbol{\psi},\boldsymbol{\pi})$ were calculable) then GMM estimation of (3.B.3) based on those observations for which $d_{it}=1$ would yield a consistent estimator of $(\beta_0, \boldsymbol{\beta}_1', \boldsymbol{\beta}_2', \boldsymbol{\kappa}', \eta)'$. In general, $\boldsymbol{\psi}$ and $\boldsymbol{\pi}$ are unknown, and so the latter estimation is infeasible. To circumvent this problem, Semykina and Wooldridge (2005) propose obtaining preliminary estimates of the selection equation parameters, $(\hat{\boldsymbol{\psi}}', \hat{\boldsymbol{\pi}}')'$ say, from a pooled probit estimation of the selection equation, and then using these estimates to obtain the sample analogue to the inverse Mill's ratio. Estimates of $(\beta_0, \boldsymbol{\beta}_1', \boldsymbol{\beta}_2', \boldsymbol{\kappa}', \eta)'$ are then obtained via GMM regression of y_{it} on $\mathbf{x}_{1,it}, \mathbf{x}_{2,i}, \bar{\mathbf{x}}_{1,i}$ and $\lambda_{it}(\hat{\boldsymbol{\psi}}, \hat{\boldsymbol{\pi}})$, using the instrument set $(1, \mathbf{z}_{1,it}', \mathbf{x}_{2,i}', \bar{\mathbf{z}}_{1,i}')'$, based on the sample of observations for which off-farm labour is supplied, that is $\{(i,t); d_{it}=1\}$. The validity of the instruments can be tested in the same way as described in the estimation approach for the on-farm labour supply equation.

The test for sample selection bias is a test of the significance of η in the GMM estimation of (3.B.3). If η is not significantly different from zero, we can estimate equation (3.B.3) without the inverse Mill's ratio with the Mundlak (1978) approach described in section 3.5. If η is significantly different from zero, still the GMM regression of y_{it} on $\mathbf{x}_{1,it}, \mathbf{x}_{2,i}, \bar{\mathbf{x}}_{1,i}$ and $\lambda_{it}(\hat{\boldsymbol{\psi}}, \hat{\boldsymbol{\pi}})$ yields consistent estimators. However, the variance of the parameters should be corrected for the fact that $\lambda_{it}(\hat{\boldsymbol{\psi}}, \hat{\boldsymbol{\pi}})$ is a generated regressor. This correction is explained in the Appendix of Semykina and Wooldridge (2005)

Chapter 4 The impact of financial status on investment decisions on Dutch dairy farms[1]

4.1 Introduction

Investments are essential for long-run economic dynamics. Expanding a building used for production, replacing an old machine with a more advanced model or closing down an unprofitable plant all have a long term impact on production. This long term focus indicates the difference with adjustment of variable inputs. Whereas in adjusting variable inputs short-run economic considerations are important, investment decisions are usually based on the expected long-term economic situation. Firms compare the expected long-term benefits of new capital goods with their current and future costs and then decide whether to invest or not. Investments therefore also reflect the expectations firms have on the economic future. Given the importance of investments it is not surprising that it has been the topic of much research in economics and other scientific fields. However, the results of many empirical studies have been modest thus far (Chirinko, 1993 and Lensink et al., 2001: 1).

An issue that has been rather controversial over time is the role of financial variables in explaining investment. Chirinko (1993) even notes that "the investment literature has been schizophrenic concerning the role of financial structure and liquidity constraints." Following the work of Modigliani and Miller (1958) stating that financial structure does not affect investment decisions, investment studies initially ignored financial variables in explaining investment (see e.g. Jorgenson, 1971). Later on however it was recognized that the assumptions of perfect information and perfect markets underlying the Modigliani-Miller model do not hold in general and that there is a role for financial variables in explaining investment. Especially in the 1990's empirical studies appeared that included financial variables like solvability, debt-asset ratio or liquidity in investment equations (see Lensink et al., 2001: 31-49 for an overview). This development was also fuelled by the fact that financial variables performed relatively well in reduced form investment equations.

A popular approach for analyzing firm investment decisions is the so-called Euler equation approach (e.g. Gardebroek, 2004). Euler equation models have their starting point in explicit long-run optimization problems of firms and yield the intertemporal equilibrium conditions for optimal investment. In other words, these models have a rather strong theoretical basis. Euler equation models also have been adapted to investigate the impact of firms' financial

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[1] Paper by Ooms, D.L. and Gardebroek, C.

structure in investment. A popular empirical strategy has been to split up the sample *ex ante* into a group of firms that are expected to be financially constrained and a group of firms that are not and then estimate Euler equations for the subgroups (Hubbard and Kashyap, 1992; Whited, 1992; Bond and Meghir, 1994). In the Euler equation for constrained firms the non-zero Lagrange multiplier associated with the binding financial constraint is then approximated by a set of financial variables. This approach however has two main drawbacks. First, the separation into financially constrained and unconstrained firms is rather subjective. Second, financial variables enter the model in a rather ad hoc way, i.e. when parameterising the Lagrange multiplier associated with the debt constraint, but they do not play a role in the setup of the theoretical model. An interesting alternative approach was proposed by Van Ees et al. (1997 and 1998). Recognizing that firms with a higher risk of going bankrupt usually pay a risk premium on their interest rate, they consider the interest rate in the Euler equation model to be firm-specific. However, they do not link these firm-specific interest rates with financial indicators.

In June 2003 the European ministers of agriculture agreed on a reform of the Common Agricultural Policy (CAP) (European Commission, 2003). Decoupled payments are introduced in this policy reform as a compensation of the reduction in intervention prices and are based on historic production. In addition, dairy farmers receive a small increase in milk quota. Decoupled payments are advocated by the WTO as a way to transfer income to farmers with minimal potential to distort production and trade (USDA, 2003). However, changing the financial situation of farmers by introducing decoupled payments can change production in the long run if investments depend on financial variables.

The objective of this paper is to investigate the effect of financial variables on investment of Dutch dairy farmers. Using the Euler equation approach, financial variables are explicitly modelled in the optimality conditions for investment by linking them to heterogeneous interest rates that are due to risk premiums. Dairy farmers in the Netherlands also face a higher interest rate when banks consider their loan application to be risky. Banks base this risk assessment mainly on financial indicators like solvability and liquidity (Van der Meulen and Venema, 2005: 42). Since we do not know the exact weights given by banks to different indicator variables we introduce a generalized cost of debt function that depends on a number of financial variables but also allows for farm-specific effects capturing e.g. management quality.

The paper is organized as follows. Section 4.2 discusses the theoretical investment model and section 4.3 deals with its empirical specification. The panel data used in estimation is described in section 4.4. Section 4.5 discusses a number of estimation issues. Results are presented in section 4.6 and section 4.7 gives conclusions and implications.

4.2 Theoretical model

The objective of dairy farmers is assumed to be maximising the expected stream of future cash flows (*CF*) at time t:

$$PV_{ht} = E_{ht}\left[\sum_{n=0}^{\infty} \rho^{n} CF_{h,t+n} \mid \Omega_{ht}\right] \tag{4.1}$$

where PV_{ht} is the expected present value for farm *h* at time *t*, E_{ht} is the expectations operator conditional on the information set Ω_{ht} available to farm *h* at time *t*, ρ is the real discount factor and CF_{ht} is cash-flow of farm *h* at time *t* that is defined as:

$$\begin{aligned} CF_{ht} = {} & p_t \bar{q}_{ht} - C(\mathbf{w}_t, \bar{q}_{ht}, \mathbf{k}_{ht}, \mathbf{z}_{ht}) - \mathbf{i}_{ht}\mathbf{p}_t^{\mathbf{i}} - \psi(\mathbf{i}_{ht}) - \kappa(\mathbf{i}_{ht}, s_{ht}, l_{ht}, d_{ht}, \boldsymbol{\mu}_h) \\ & + (d_{ht} - d_{h,t-1}) + r_{2t} \cdot m_{ht} - (m_{ht} - m_{h,t-1}) \end{aligned} \tag{4.2}$$

Equation (4.1) is maximized subject to the constraints:

$$\mathbf{k}_{ht} = \mathbf{i}_{ht} + (\mathbf{1} - \boldsymbol{\delta})' \times \mathbf{k}_{h,t-1} \tag{4.3}$$

$$\mathbf{k}_{ht}, \mathbf{k}_{h,t-1}, \mathbf{z}_{ht}, d_{ht}, d_{h,t-1}, m_{ht}, m_{h,t-1} \geq 0 \tag{4.4}$$

where × represents element by element multiplication.

Equation (4.2) defines cash flows for farm *h* in year *t* as revenues of production minus variable costs, gross investment expenditure, adjustment costs and the cost of debt plus interest received on savings and the changes in debt and savings. This cash flow function resembles that of e.g. Hubbard and Kashyap (1992) except that we also include savings in our model. Moreover, Hubbard and Kashyap (1992) and others restrict total cost of debt to be debt times a non-farm-specific interest rate. Production in year *t* is equal to the binding quota level $\bar{q}_{ht}$, output price is p_t and variable costs are represented by a short-run cost function *C*(.)

that depends on a vector of input prices $\mathbf{w}_t$, quota level $\bar{q}_{ht}$, a vector of quasi-fixed capital levels $\mathbf{k}_{ht}$ and a vector of fixed factor levels $\mathbf{z_{ht}}$ (e.g. labour and land). This cost function is assumed to be continuous, non-decreasing and concave in input prices, linear homogeneous in all prices and non-increasing and convex in (quasi-)fixed inputs. The convexity in quasi-fixed inputs makes the short-run cost function consistent with long-run cost minimisation (Chambers, 1988: 109). In a short-run cost function, quasi-fixed inputs set boundaries on cost minimisation. We assume investments to be shifts rather than removals of these boundaries. This allows for the use of a short-run cost function in investment models. Each period, farmers decide on investments denoted by the vector of gross investment $\mathbf{i}_{ht}$ containing the elements i_{jht} given the investment price vector $\mathbf{p}_t^{\mathbf{i}}$ containing the elements p_{jt}^{i} for $j=1,2$ representing buildings and machinery respectively. In principle investment can be positive or negative. Note that a negative investment implies revenue to the farmer. Gross investment expenditure consists of the expenditure on new capital goods minus the revenues from capital goods sold. Moreover, in equation (4.2) it is assumed that when farmers invest in these quasi-fixed factors, there are adjustment costs. Examples of adjustment costs are learning costs, costs of restructuring the production process, costs associated with building licenses or environmental licenses, the value of time spent on preparing the investment and so on. These costs are represented by the adjustment cost function $\psi(.)$ that depends on the size of gross investments in buildings and machinery in year t. The following basic assumptions regarding the adjustment cost function are made: $\psi(.)$ is non-negative, increases in investment (at an increasing rate in the limit) and is zero at zero investment.

Farmers pay interest on debt. The total amount of interest paid on debt is represented by the cost of debt function $\kappa(.)$. The amount of debt varies over farms and years, but also the interest rate paid on debt. The motivation for this is that banks charge higher interest rates to farmers with a weak financial position than they charge to farmers having a solid financial situation. The higher interest rate is due to a farm specific risk premium added to the base interest rate. The worse the financial position, the higher this risk premium is. This assumption implies that farmers can always borrow but at an increasing price. The cost of debt function contains a number of financial variables that indicate the financial position of the farm. Survey work (Van der Meulen and Venema, 2005: 42) shows that important indicators for banks in deciding upon loans and interest rates are solvability (s) and liquidity (l). Cost of debt is assumed to decrease in these two variables. We also assume that total level of debt (d) has a positive impact on the cost of debt. Since the cost of debt is the price paid for debt it is obvious that the higher the total level of debt, the higher the cost of debt. Moreover, farmers with already a large amount of debt or applying for large loans may face higher interest rates. Personal characteristics like the financial reputation of the farmer, his managerial quality, business plan presented to the bank etc. may also play a role in the loan application. These unobserved characteristics are represented by a farm specific effect (μ_h). Investments have an impact on the cost of debt since investments usually imply new borrowing, which leads to new negotiations with the bank on loans and interest rate to be paid.

The final terms in equation (4.2) indicate that cash-flows in year t may also change due to a change in debt ($d_t - d_{t-1}$), i.e. because of new debt or repayment, interest received on savings ($r_2 m_t$) or because of a change in savings ($m_t - m_{t-1}$), where m_t indicates farm savings in year t. Equation (4.3) gives the capital accumulation identities, stating that the current stock of a capital good consists of last year's capital stock, corrected for depreciation ($\boldsymbol{\delta}$ is a vector of depreciation rates, allowing for different depreciation rates for different investment goods), plus current investment in that capital good. **1** is a vector of ones with the same dimension as $\boldsymbol{\delta}$ (2 by 1 in this research).

Substituting $\mathbf{i}_t$ using equation (4.3) and differentiating the objective function (4.1) with respect to the element k_t in $\mathbf{k}_t$ corresponding to i_t gives the following first-order condition:

$$E\left[-\frac{\partial C(\cdot)}{\partial k_{jht}} - p^i_{jt} - \frac{\partial \psi_t(\cdot)}{\partial i_{jht}} - \frac{\partial \kappa_t(\cdot)}{\partial i_{jht}} \right.$$

$$\left. + \rho(1-\delta_j)\left(p^i_{j,t+1} + \frac{\partial \psi_{t+1}(\cdot)}{\partial i_{jh,t+1}} - \frac{\partial \kappa_{t+1}(\cdot)}{\partial i_{jh,t+1}}\right)\right] = 0 \qquad j=1,2 \qquad (4.5)$$

where δ_j is the depreciation rate in $\boldsymbol{\delta}$ corresponding to i_j. Equation (4.5) implies that in an optimal long-term investment strategy, marginal costs of investment (consisting of the unit investment price, the marginal adjustment costs and the marginal risk premium in the cost of debt[2]) should be equal over time. Large investments lead to changes in the interest rate and thus to changes in the cost of debt. If there is no investment, the cost of debt also doesn't change. Note that investment in period t implies a change in the marginal cost due to the change in the capital stock.

[2] Since we defined the cost of debt function such that current investment has an impact on the risk premium in the cost of debt and only through that on the total cost of debt, $\partial \kappa_t / \partial i_{jht}$ represents the marginal change in risk premium and not the marginal cost of debt.

4.3 Empirical model

In order to estimate equation (4.5) functional forms have to be specified for the short-run cost function, the adjustment cost function and the cost of debt function. For the short-run cost function, a quadratic functional form with prices of two variable inputs (cattle and a composite of other variable inputs), minus the price of other output (all output except milk output), milk quota, two quasi-fixed capital goods (buildings and machinery) and three fixed factors (family labour, land and technology) is used. Other output generates revenue and is therefore seen as negative costs in the following cost function:

$$C(\mathbf{w}_{ht}, \mathbf{k}_{ht}, \mathbf{z}_{ht}) = \alpha_0 + \sum_{g=1}^{7} \alpha_g x_{ght} + \frac{1}{2} \sum_{g=1}^{7} \sum_{n=1}^{7} \alpha_{gn} x_{ght} x_{nht} \tag{4.6}$$

where x_{1ht} denotes machinery, x_{2ht} buildings, x_{3ht} milk quota, x_{4ht} price of cattle, x_{5ht} minus the price index of other outputs, x_{6ht} family labour and x_{7ht} land. The alphas are parameters. Linear homogeneity in prices is imposed by dividing the price of cattle and the price index of other outputs by the price index of a composite of variable inputs.

For the adjustment cost function the following flexible specification is used for positive investment in buildings and machinery:

$$\psi(\mathbf{i}_{ht}) = \mathbf{i}_{ht} \boldsymbol{\beta}_{1h} + 0.5 \mathbf{i}_{ht}^2 \boldsymbol{\beta}_2 \tag{4.7}$$

where $\mathbf{i}_{ht}^2$ is the element by element square of the vector $\mathbf{i}_{ht}$, $\boldsymbol{\beta}_{1h}$ is a farm-specific vector with linear adjustment cost terms and, in line with the investment literature, $\boldsymbol{\beta}_2$ is expected to be positive leading to convex adjustment costs. $\boldsymbol{\beta}_{1h}$ and $\boldsymbol{\beta}_2$ are parameter vectors containing the parameter values for the different investment goods. This specification allows for different adjustment costs for different investment goods, it nests a number of well-known specifications (e.g. linear and convex quadratic) and it also has a number of desirable properties. First, the linear term $\mathbf{i}_{ht} \boldsymbol{\beta}_{1h}$ implies a threshold for investment, since the dynamic shadow price of capital has to exceed the marginal adjustment cost implied by $\boldsymbol{\beta}_{1h}$. Together with the unit purchase price, this non-zero marginal adjustment cost provides an additional explanation for observed asset fixity (Hsu and Chang, 1990). Second, allowing the linear term to be farm-specific accounts for differences in adjustment costs between farms. So, farms may have different costs of environmental licenses, different administrative or search costs or different production losses due to restructuring of the production process. In other words investment thresholds are different for individual farms.

The cost of debt function is specified as follows:

$$\kappa(\mathbf{i}_{ht}, d_{ht}, s_{ht}, l_{ht}, \boldsymbol{\mu}_h) = r_{1ht} d_{ht} + \mathbf{i}_{ht} \cdot (\boldsymbol{\gamma}_1 d_{ht} + \boldsymbol{\gamma}_2 s_{ht} + \boldsymbol{\gamma}_3 l_{ht} + \boldsymbol{\mu}_h) \tag{4.8}$$

Cost of debt in period t is equal to the level of debt in period t times a time and farm-specific interest rate r_{1ht} to be paid on debt, reflecting interest rates negotiated in the past, plus a term that changes the cost of debt when a farmer invests. In that case the farmer goes to the bank and negotiates a new interest rate. This cost of debt then also depends upon the financial situation of the farm and personal characteristics of the farmers as argued in section 4.2. The functional form of this part is chosen such that it is zero for zero investment. In other words, if there is no investment, the interest rate negotiated in the past remains the same and the cost of debt only changes in case debt in period t is less than in period t-1 in this period due to repayments. The vectors $\boldsymbol{\gamma}_1 - \boldsymbol{\gamma}_3$ allow for different effects of financial variables in interest rate negotiations. These differences are plausible since different investment goods have different characteristics like e.g. different salvage values. The cost of debt function is assumed to be non-decreasing in d_t and non-increasing in s_t and l_t.

Taking partial derivatives of equations (4.6), (4.7) and (4.8) and substituting them into equation (4.5) and assuming that farmers have rational expectations, which allows for substituting expected values by the observed values and introducing an error term (ε_{jht}) with expectation zero, gives the following equation to be estimated for investment in capital good j:

$$\begin{aligned}
&-\alpha_j - \sum_{n=1}^{7} \alpha_{jn} x_{nht} - p^i_{jt} - \beta_{j1h} - \beta_{j2} i_{jht} \\
&\quad - (\mu_{jh} + \gamma_{j1} d_{ht} + \gamma_{j2} s_{ht} + \gamma_{j3} l_{ht}) \\
&\quad + \rho(1-\delta_j)\big[p^i_{j,t+1} + \beta_{j1h} + \beta_{j2} i_{jh,t+1} \\
&\quad + (\mu_{jh} + \gamma_{j1} d_{h,t+1} + \gamma_{j2} s_{h,t+1} + \gamma_{j3} l_{h,t+1})\big] = \varepsilon_{jh,t+1} \qquad j=1,2
\end{aligned} \tag{4.9}$$

4.4 Data

This section gives a description of the data used in estimation. The farm specific data come from the LEI rotating panel data set of Dutch farms. A farm is classified to be a dairy farm if its returns consist for 50 per cent or more of milk revenues. The data set consists of 6338 observations on 1307 farms. The period investigated is from 1987/88 until 1999/00. National data come from Statistics Netherlands (CBS). The implicit quantities of buildings, machinery and milk output are obtained by dividing the total values of these variables by their corresponding price index. For buildings and machinery the Tornqvist price index is used. These price indices are also used as investment price indices. The amount of investment in machinery and buildings is derived in two steps. First, it is determined whether the difference in capital goods between two subsequent years differs from the depreciation. If this is the case we conclude investment took place. For buildings we observe many zero investments. Second, we construct the implicit investment amount by dividing the value of investment by the corresponding price index. Other price variables used are a Tornqvist price index for variable input, the price index for cattle, and a Tornqvist price index for other output. Variable input contains, amongst others, feed, veterinary costs and hired labour. Cattle consist of cows aged one year and older. Other output contains marketable crops, veal, pigs, poultry and other farm revenues. Family labour is defined as total number of family hours worked on the farm. Land is the number of hectares used by the farmer. Debt is the total value of short and long-term debt at the beginning of the year. Assets are the total value of all the belongings of the farm at the beginning of a year and are calculated by the LEI. From this the solvability is calculated as the ratio between assets minus debt and assets. Liquidity is the amount of available means for repaying short term debt. We use working capital, which is an absolute measure of liquidity (Barry et al., 1995: 108). Working capital is the difference between farm assets that are convertible into money at a short term notice and short term debt. The former includes among others cattle, stocks and cash money and claims to other parties. The latter includes among others short term loans and preliminary received payments of other parties. Table 4.A1 in Appendix 4.A gives an overview of the units, mean and standard deviation of the variables used.

4.5 Estimation

The equation to be estimated (4.9) contains a discount factor and depreciation rates for all investment goods. We fix the discount factor and the depreciation rate before estimation, which makes equation (4.9) linear in parameters. The discount factor used is the average over the estimation period, 0.95, and is based on the real interest rate. The depreciation rate is assumed to be 10 per cent for machinery and 5 per cent for buildings. The price variable for machinery is the only variable in this equation that does not have an accompanying parameter. This implicitly makes it the dependent variable in estimation. The price index has limited variation, because it does not vary between farms. Since econometric estimation is based on the explanation of variation in the dependent variable we choose to rewrite (4.9) such that investments become the dependent variable. This results in the following equation:

$$
\begin{aligned}
& i_{jh,t+1} - \frac{1}{\rho(1-\delta_j)} i_{jht} = \\
& \quad \theta_{j0} + \theta_{jp}\left(\frac{1}{\rho(1-\delta_j)} p^i_{jt} - p^i_{j,t+1} \right) + \frac{1}{\rho(1-\delta_j)} \sum_{n=1}^{7} \theta_{nl} x_{nht} \\
& \quad + \sum_{c=1}^{3} \theta_{fjc}\left(\frac{1}{\rho(1-\delta_j)} y^i_{cht} - y^i_{ch,t+1} \right) + a_{jh} + e_{jh,t+1} \qquad j=1,2 \qquad (4.10)
\end{aligned}
$$

where i_{jht} is investment for farm h at time t, p^i_{jt} is investment price at time t and y represent the financial variables d, s and l. Furthermore, $\theta_{j0} = \alpha_j / (\rho(1-\delta_j)\beta_{j2})$, $\theta_{jp} = 1/\beta_{j2}$, $\theta_{jl} = \alpha_{jl} / \beta_{j2}$, $\theta_{fjc} = \gamma_{jc} / \beta_{j2}$, $a_{jh} = ((\beta_{jh} + \mu_{jh})(1/(\rho(1-\delta_j)) - 1)) / \beta_{j2}$ and $e_{jh,t+1} = \varepsilon_{jh,t+1} / (\rho(1-\delta_j)\beta_2)$.

First differences of the variables in (4.10) are taken to eliminate the farm specific effect a_{jh}. This transformation results in a dependent variable for estimation containing observations of period t-1, t and t+1. To obtain sample moment conditions that can be expected to be zero, two periods lagged observations of all variables are used as instruments. This implies that for one observation used in estimation four subsequent observations of a farm are needed. The last three investment observations of these four have to be positive, since equation (4.5) and therefore equation (4.10) only holds for positive investments. Extra instruments are added for dependent variables in (4.10) that are assumed exogenous. These are the composite terms of these variables as they appear in (4.10).

The two step GMM estimation in this research is based on the moment condition:

$$E[\Delta e_{jh,t+1}\mathbf{z}_{h,t+1}] \quad = \quad \mathbf{0} \tag{4.11}$$

for all useful observations explained above. E is the expectation operator, $\Delta e_{jh,t+1}$ is in first differences[3], and $\mathbf{z}_{h,t+1}$ is a $q \times 1$ vector with instrument values for individual h at time t+1 explained above. The GMM estimator used to estimate the vector of unknown variables, $\boldsymbol{\theta}$, is

$$\hat{\boldsymbol{\theta}} = \mathbf{Q}^{-1}\left(\sum_{h=1}^{H}\Delta\mathbf{x}_h\text{'}\mathbf{z}_h\right)\left(\sum_{h=1}^{H}\mathbf{z}_h\text{'}\Delta\hat{\mathbf{e}}_h\Delta\hat{\mathbf{e}}_h\text{'}\mathbf{z}_h\right)^{-1}\left(\sum_{h=1}^{H}\mathbf{z}_h\text{'}\Delta\mathbf{y}_h\right) \tag{4.12}$$

where H is the number of farms in the data set, $\Delta\mathbf{x}_h = (\Delta\mathbf{x}_{h3},...,\Delta\mathbf{x}_{h,T-1})\text{'}$, T is the total number of time periods in the data set, $\mathbf{x}_{ht}$ is a p × 1 vector with the explanatory variables of (4.10), $\mathbf{z}_h = (\mathbf{z}_{h3},...,\mathbf{z}_{h,T-1})\text{'}$, $\Delta\mathbf{y}_h = (\Delta y_{h3},...,\Delta y_{h,T-1})\text{'}$, $\Delta\mathbf{e}_h = (\Delta e_{h3},...,\Delta e_{h,T-1})\text{'}$,

$$\mathbf{Q} = \left(\sum_{h=1}^{H}\Delta\mathbf{x}_h\text{'}\mathbf{z}_h\right)\left(\sum_{h=1}^{H}\mathbf{z}_h\text{'}\Delta\hat{\mathbf{e}}_h\Delta\hat{\mathbf{e}}_h\text{'}\mathbf{z}_h\right)^{-1}\left(\sum_{h=1}^{H}\mathbf{z}_h\text{'}\Delta\mathbf{x}_h\right) \tag{4.13}$$

and $\hat{\mathbf{e}}_h$ is created with a first step estimator of $\boldsymbol{\theta}$ using equations (4.12) and (4.13) without the term $\hat{\mathbf{e}}_h\,\hat{\mathbf{e}}_h\text{'}$. The approximate large sample variance for the estimator is:

$$\mathbf{V} = \mathbf{Q}^{-1} \tag{4.14}$$

In this research we have an unbalanced data set. If there is no observation for farm h at time t, its corresponding variables are zero in the equations above.

To see whether the initial structure of the model is correct, we use Sargan's *J*-test of overidentifying restrictions (Hall, 2005: 47). If there are q moment conditions[4] and p parameters, there are q - p overidentifying restrictions. In Sargan's J-test:

[3] For example: $\Delta e_{j,t+1} = e_{j,t+1} - e_{jt}$.

[4] This means that there are q instruments.

$$J=\left(\sum_{h=1}^{H}\Delta\hat{\boldsymbol{\varepsilon}}_h{}'\mathbf{z}_h\right)\left(\sum_{h=1}^{H}\mathbf{z}_h{}'\Delta\hat{\mathbf{e}}_h\Delta\hat{\mathbf{e}}_h{}'\mathbf{z}_h\right)^{-1}\left(\sum_{h=1}^{H}\mathbf{z}_h{}'\hat{\boldsymbol{\varepsilon}}_h\right) \tag{4.15}$$

where $\hat{\boldsymbol{\varepsilon}}_h$ is the vector of residuals created with $\hat{\boldsymbol{\theta}}$ of equation 2.8. The null hypothesis of this test is that the over-identifying restrictions hold, and hence that the initial structure of the model is correct. The test statistic has a χ^2_{q-p} distribution under the null-hypothesis.

4.6 Results

The estimation method described in the previous section results in 2519 useful observations for estimation of the investment in machinery equation (*j*=1) and only 521 useful observations for estimation of the investment in buildings equation (*j*=2). The latter appeared to be too little for efficient estimation of (4.10), which became apparent by the fact that none of the parameters where significant in estimation. Therefore, this section only presents the estimation results for investment in machinery. We use milk output as a proxy for milk quota here. The reason for this is this is that we use the cost of milk output to derive (4.10). Investment in machinery is a medium term decision. Adjusting machinery is not as easy as adjusting for instance feed, which is a short term decision. On the other hand, it is not as difficult as adjusting buildings and land, which are long term decisions. This classification is backed up by the data where investments in machinery occur almost in every year for every farmer, whereas investments in buildings and land are observed much less frequent. We assume the exogeneity of buildings and land in the investment in machinery equation. Price data in this research are national price indices. National prices are not influenced by the actions of one farmer. For this reason we also assume the exogeneity of the price indices for machinery, cattle and other output. Recall from the previous section that the exogenous variables are used as instruments in estimation. This allows us to test our assumptions by testing the validity of each moment condition.

The objective of this paper is to investigate the potential effect of financial variables on investment decisions. Therefore, we estimate (4.10) with and without the financial variables and test the two models against each other. Table 4.1 gives the parameter estimates and t-ratios for equation (4.10) for both the model with and the model without financial variables.

Table 4.1. Parameters and t-ratios for the investment in machinery equation

	Model with financial variables		Model without financial variables	
	Estimate	t-ratio	Estimate	t-ratio
θ_{1p} (price of machinery)	0.16	1.65*	0.15	1.99**
θ_{11} (machinery)	0.30	1.02	0.31	1.20
θ_{12} (buildings)	0.88	1.15	0.95	3.03**
θ_{13} (milk output)	0.34	1.22	0.33	1.43
θ_{14} (cattle price)	-0.72	-1.24	-0.78	-2.49**
θ_{15} (other output price)	0.83	1.88*	0.85	2.77**
θ_{16} (labour)	0.24	1.55	0.22	1.72*
θ_{17} (land)	-0.13	-1.05	-0.12	-1.22
θ_{f11} (debt)	0.74	0.10		
θ_{f12} (solvability)	-0.39	-0.00		
θ_{f13} (liquidity)	0.19	0.10		
J-test statistic		6.80		6.83
Degrees of freedom (df)		6		9
Probability $\chi^2_{df} > \mathrm{J}$		0.24		0.56
D test statistic				0.03
Degrees of freedom (df)				3
Probability $\chi^2_{df} > \mathrm{J}$				1.00

** and * indicate significance at the 5 and 10 per cent level respectively.

The parameters associated with the financial variables debt, solvability and liquidity are all individually not significantly different from zero. To test whether they are jointly different from zero we perform a D or LR-type test (Hall, 2005: 162). The test statistic of this test is the J-statistic value of the restricted model (6.83) minus the J-statistic value of the unrestricted model (6.80) and is χ^2-distributed with 3 degrees of freedom, which is equal to the number of restrictions. The D-test statistic has value 0.03. This does not exceed the 10 per cent critical value of the χ^2_3 distribution (6.25). Therefore, we conclude that the financial variables can be dropped from the model[5]. An implication of this finding is that direct income payments as proposed in recent EU dairy reforms do not have an effect on investment in machinery in case these payments would lead to changes in e.g. solvability or liquidity.

The resulting model without financial variables has a J-test statistic of 6.83, which does not exceed the 10 per cent critical value of the χ^2_9 distribution (15.99). Therefore, the model without financial variables is not rejected. Recall from section 4.3 that β_2 should be positive. The estimated parameter $\theta_p = 1/\beta_2$ is significantly positive. Since the price of machinery was multiplied by 100 to scale the parameters, this leads to a significant quadratic adjustment cost

[5] In the model with financial variables the factor inputs have insignificant parameter estimates as well. Leaving these out does not lead to significant parameters for the financial variables. The same holds for leaving the price variables out. This leads to the conclusion that the financial variables are not important in this model.

parameter of 0.067, providing evidence for the existence of adjustment costs. Since the farm-specific linear adjustment costs parameters are contained in the overall farm-specific effect a_h we cannot calculate adjustment costs for different investments made by farmers. θ_{12} and θ_{16} are significantly positive. This implies that farms that have relatively a lot of buildings and labour invest more, which is an intuitively plausible result. θ_{14} is significantly negative. This implies farmers invest less if the price of cattle goes up. Apparently farmers become careful when an input price increases. The opposite effect with respect to output price is than expected and shown by the significantly positive value of θ_{15} associated with other output price.

4.7 Summary and conclusions

This paper proposes a new way of modelling the impact of financial variables on investment decisions. Advantages of our approach over existing approaches are that financial variables are explicitly incorporated in the theoretical framework in stead of adding them *ex post* to the empirical investment equations and that no subjective classification of firms believed to be financially constrained has to be made. Our model is estimated using data on machinery investments of Dutch dairy farms. Based on the literature, solvability, liquidity and total amount of debt were included as financial variables.

The estimation results show that the included financial variables do not have a significant effect on investment in machinery. An explanation for this could be that farmers do not change their amount of debt when they invest in new machinery but finance these investments from savings from the current or previous year. An implication of this finding is that direct income payments as proposed in recent EU dairy reforms do not have an effect on investment in machinery in case these payments would lead to changes in e.g. solvability or liquidity.

Our results show that for investment in machinery adjustment costs are convex in investment, i.e. with increasing investment these costs increase more than proportionally. In other words for machinery investment in dairy farming it is attractive to smooth larger investments over time.

Given the model structure and the occurrence of many zero observations for investment in buildings, the model estimated for this capital good appeared so inefficient that no reliable conclusions can be made based on these models. However, since investments in buildings are usually much larger it is worthwhile to investigate whether financial variables have an impact on it. Future work should therefore focus on developing alternative investment models in which the structural investment equations can be estimated even with many zero investments observed.

Appendix 4.A: Data

Table 4.A1: Data for average specialised dairy farm in the Netherlands in 1999/00.

Variable	Unit	Mean	Standard deviation
Investments			
Investment in machinery[a]	1000 Euro of 1999	17.36	27.55
Investment in buildings[b]	1000 Euro of 1999	33.98	109.87
Output			
Milk output	1000 Euro of 1999	134.08	83.65
Prices indices			
Machinery price index	1991 = 1	0.92	
Buildings price index	1991 = 1	1.13	
Input price index	1991 = 1	0.92	
Cattle price index	1991 = 1	0.90	
Other output price index	1991 = 1	0.90	
Factor inputs			
Machinery	1000 Euro of 1999	81.95	54.55
Buildings	1000 Euro of 1999	198.48	110.52
Labour	Hours	4068	1484
Land	Hectares	35.26	19.82
Financial variables			
Debt	1000 Euro of 1999	353.63	327.83
Solvability	Percentage	72.55	18.02
Liquidity	1000 Euro of 1999	128.86	147.66

[a] Investment in machinery is positive for 100 per cent of observations.

[b] Investment in buildings is positive for 54.0 per cent of observations. The reported values are for positive observations.

Chapter 5 Farm growth and exit as determinants of production structure in Dutch dairy farming[1]

5.1 Introduction

The number of dairy farms in The Netherlands is decreasing. At the same time the average size of dairy farms is increasing. This shows that the production structure of Dutch dairy farming is changing. Exit and farm growth result from the behaviour of individual farmers. Besides factors affecting (future) income from dairy farming, e.g. input and output prices, household characteristics and preferences play a role in both exit and farm growth. Policy also affects exit and farm growth. For example, the 2003 CAP reform is expected to change income. A reduction in income could lead to the decision to stop dairy production. However, some farmers might decide to grow to ensure continuity. In analysing the effects of policy changes on dairy farming quantifying the effects on exit and farm growth have not been taken into account in chapters 2, 3 and 4 but also not in previous micro-economic research on Dutch dairy farming. For example, Ooms and Peerlings (2005) calculate the short term effects of the 2003 CAP on income for individual farms but they do not take into account exit or buying of milk quota (growth). Boots, et al. (1997) do take into account quota trade in a policy model of Dutch dairy farming, and therefore growth, but they do not take into account exit. Jongeneel et al. (2005) do look at policy effects on farm size distribution, but do not consider exit and growth of individual farms.

Kimhi and Bollman (1999) look at exit of farms in Canada and Israel but they do not look at farm growth. Ahearn et al. (2005) analyse the effects of policies on the probability that a farm grows and exits in the US for 1982-1997. However, they do not explicitly formulate a growth model. Moreover, they do not consider individual farms in their estimation. Weiss (1998) does formulate a growth model for individual farms. However, even though he has the availability of panel data, he does not take advantage of this in his estimation procedures. Foltz (2004) also formulates a growth model and does take advantage of the availability of panel data on a sample of Connecticut dairy farmers in estimation of survival (the complement of exit) and growth models. Connecticut dairy farmers do not produce under a milk quota regime though.

In the literature described above, as in all literature on farm exit, exit is modelled as a short term change, i.e. exit is defined as not observing production in the present year given the information in the previous year. This implies actual exit in that previous year. Exit, however,

[1] Paper by Ooms, D.L. and Peerlings, J.H.M.

is a large disinvestment that can take some time to arrange properly. Therefore, it can be that a decision to exit can lead to an actual exit only after a few years. The decision to exit is however still taken given the available information at the time the decision is made. Therefore, we will, next to the traditional way of modelling exit, look at the effects of the information of a certain year on exit within the medium term.

In this paper we will define and estimate models of dairy farm exit and growth under a quota regime. We consider exit both in the short term (exit in the same year as the exit decision is taken) as the medium term (within three years after the exit decision is taken). We explore the possibilities of using panel data estimation techniques that allow for farm specific effects. These can represent a wide range of unobserved characteristics. Examples of these are managerial ability that allows farmers to benefit from the possibilities of economies of scale, but also household preferences that make that farmers grow to be able to continue their farm. With estimated growth and exit models it is possible to make farm specific statements about the 2003 CAP reform.

The purpose of this chapter is to estimate exit and growth models of Dutch dairy farms in order to make farm specific statements about the 2003 CAP reform. Exit is defined as stopping dairy farming. Farm growth is defined as the change in quota amounts (a reduction being negative growth). A negative growth could imply that a dairy farm is no longer considered to be a specialised dairy farm. However, this is not considered as exit.

In this research we only look at the growth and exit of specialised dairy farms. In 1999, the last year of the main data set in this research, these farms own 94.8 per cent of total milk producing cows and represent 87.8 per cent of all farms producing milk[2].

Section 5.2 presents the theoretical models of farm exit and growth and section 5.3 their empirical counterparts. Section 5.4 describes the data used in estimation. The estimation techniques used are described in section 5.5. Section 5.6 presents the estimation results. The possible effects of the 2003 CAP reform are discussed in section 5.7. Finally, section 5.8 concludes the chapter.

[2] These numbers are calculated from the data set containing all farms that have a positive number of dairy cows.

5.2 Theoretical models

In this section an exit and farm growth model are specified. We omit the subscript for individual farms to simplify notation.

5.2.1 Exit

A farm household has at the beginning of a period the choice to continue or exit dairy farming. We assume the farm household maximises utility over the relevant period given an intertemporal budget constraint. In the case the farm household continues dairy farming; income equals farm profit from dairy farming plus off-farm labour income and external non-labour income. We assume milk production to be equal to the amount of milk quota. The farm's maximisation problem can be expressed as the following value function:

$$
\begin{aligned}
&V^d = \max_{c_t, m_t} \sum_{t=1}^{T} \beta_t U(\mathbf{c}_t \mid \mathbf{z}_t^u) \\
&s.t. \sum_{t=1}^{T} \beta_t \mathbf{p}_t^c{}' \mathbf{c}_t \leq \sum_{t=1}^{T} \beta_t \left(\pi_t(\mathbf{p}_t, \mathbf{w}_t, h_t^{on}, \mathbf{k}_t^{on}, m_t) + p_t^L h_t^{off} + y_t^{off} \right)
\end{aligned}
\tag{5.1}
$$

where β_t is the discount rate in year *t*, U is utility, $\mathbf{c}_t$ is a vector of consumption goods in year *t*, $\mathbf{z}_t^u$ is a vector of utility shifting household characteristics in year *t*, $\mathbf{p}_t^c$ is a vector of prices of consumption goods in year *t*, π_t is profit in year *t*, $\mathbf{p}_t$ is a vector of prices of variable outputs in year *t*, $\mathbf{w}_t$ is a vector of prices of variable inputs in year *t*, h_t^{on} is quantity of labour employed on-farm in year *t*, $\mathbf{k}_t^{on}$ is a vector of capital quantities used on-farm in year *t*, m_t is quantity of milk production in year *t*, p_t^L is off-farm wage in year *t*, h_t^{off} is quantity of labour employed off-farm in year *t*, y_t^{off} is external non-labour income in year *t* and *T* marks the end of the period.

The utility function includes preferences of the farm household, e.g. to remain in dairy farming. The length of the time period is determined by whether or not there is a successor and by the age of the farmer.

If the farm exits dairy farming we have a similar optimization problem but either the profit of farming is zero if the farm household quits farming as a whole or the profit from farming does not come from dairy farming. The outcome of the optimisation in case of exit is V^e. If:

$W = V^e - V^d \leq 0$ the household continues dairy farming, if $W = V^e - V^d > 0$ it exits dairy farming. Both V^e and V^d depend on the variables determining farm profits and off-farm income.

5.2.2 Growth

Part of the intertemporal budget constraint in equation (5.1) is the profit function. This profit function shows the maximum profit as a function of output prices, variable input prices, quantity of labour employed on-farm, quantity of capital used on-farm, the quantity of milk production and the milk price. We assume milk production to be equal to the milk quota. Foltz (2004) shows how by extending equation (5.1) with an investment model the optimal amount of capital can be determined. Here we assume in the optimization that the quantity of capital used on-farm and labour employed on-farm and are fixed. However, we assume that the quota amount can be adjusted every year such that profit is maximized. In other words we treat the amount of milk production as a variable output. Next we derive the optimal milk production or amount of milk quota. Even though the quota amount can be adjusted every year the quota amount in each year is restricting milk production. Moschini (1988) proposes to take this into account by writing the profit function in equation (5.1) as:

$$\pi_t(\mathbf{p}_t, \mathbf{w}_t, h_t^{on}, \mathbf{k}_t^{on}, m_t) = \pi_t^*(\mathbf{p}_t, \mathbf{w}_t, h_t^{on}, \mathbf{k}_t^{on}, m_t) + p_t^m m_t \tag{5.2}$$

where π_t^* is restricted profit in year *t*. π_t^* should be seen as the revenue of all non-restricted outputs minus the costs of all variable inputs, when the supply of outputs and the demand of inputs is optimal, given the amounts of factor inputs and milk output.

From the profit function the shadow price of milk production (marginal cost of milk production) and the shadow price of milk quota can be derived:

$$q_t^m(.) = -\frac{\partial \pi_t^*(\mathbf{p}_t, \mathbf{w}_t, h_t^{on}, \mathbf{k}_t^{on}, m_t)}{\partial m_t} \tag{5.3}$$

$$q_t^q(.) = \frac{\partial \pi_t(\mathbf{p}_t, \mathbf{w}_t, h_t^{on}, \mathbf{k}_t^{on}, m_t)}{\partial m_t} = p_t^m - \frac{\partial \pi_t^*(\mathbf{p}_t, \mathbf{w}_t, h_t^{on}, \mathbf{k}_t^{on}, m_t)}{\partial m_t} = p_t^m - q_t^m \tag{5.4}$$

where q_t^m is the shadow price of milk production in year *t* and q_t^q is the shadow price of milk quota in year *t*.

The shadow price of the milk quota is given by the milk price minus this shadow price of milk production. It gives the extra profit of one unit of extra milk quota for a farm.

A farm will buy (sell) milk quota if its shadow price of the quota is larger (smaller) than the market price. It will trade quota till the point where both prices are equal. The optimal milk production can be found by taking the inverse of the shadow price equation of the milk quota (equation 4) and substituting the shadow price of the quota for the market price of the quota.

$$m_t^n = m_t^n(\mathbf{p}_t, \mathbf{w}_t, h_t^{on}, \mathbf{k}_t^{on}, p_t^q) \qquad (5.5)$$

where m_t^n is the optimal level of milk production in year *t*, p_t^q is the price of milk quota in year *t*.

The change in milk production, or growth of the farm measured in milk quotas, is given by

$$\begin{aligned} \Delta m_t &= m_t^n - m_t \\ \Delta m_t &= 0 \quad if \quad p_t^q = p_t^m - q_t^m \\ \Delta m_t &> 0 \quad if \quad p_t^q < p_t^m - q_t^m \\ \Delta m_t &< 0 \quad if \quad p_t^q > p_t^m - q_t^m \end{aligned} \qquad (5.6)$$

where Δm_t is change in milk production in year *t*.

Equation (5.6) shows the continuous adjustment of the level of milk quota to maximise profit. This continuous adjustment is part of the utility maximisation in equation (5.1). Equation (5.1) shows that in the long-term in a utility maximising context there could be a trade-off between farm profit from dairy farming and alternative sources of income, i.e. off-farm labour income and external non-labour income.

5.3 Empirical models

This section describes the empirical models used in this research to find the factors determining exit and growth of Dutch dairy farms.

5.3.1 Exit

We are interested in a model that explains the exit from dairy farming for the population of specialised dairy farms. In the theoretical exit model, described in section 5.2.1, it is explained that farms exit from milk production if the maximised future utility of the farm is lower with the dairy activity than without the dairy activity. Equation (5.1) shows that the maximisation of utility is restricted by available income. It also shows that available income depends on the variables influencing farm profit, the off-farm wage index and external non-labour income. Next to that it shows that utility is conditional on farm characteristics. All these variables are used to describe exit in the empirical model that we develop in this section.

In the short term exit model exit is assumed to take place in the same year as the decision to exit is taken. Therefore, not observing production in year t is explained by information of year t-1. To this end we define the following index function for the short term exit equation

$$s_{it} = \begin{cases} 1 \text{ if } \mathbf{w}_{i,t-1}'\boldsymbol{\delta} + \nu_{it} > 0 & \text{(farmer decides to exit)} \\ 0 \text{ otherwise} & \text{(farmer decides not to exit)} \end{cases} \tag{5.7}$$

where s_{it} is an indicator variable with value 1 if farm i is not producing milk at time t (exit from dairy farming) and 0 if farm i is still producing milk at time t (survival). Note that in this definition, $s_{it} = 1$ reflects exit from milk production and not necessarily exit from farming. $\mathbf{w}_{i,t-1}$ is a vector of explanatory variables that are exogenous with respect to s_{it}, $\boldsymbol{\delta}$ is a parameter vector to be estimated and ν_{it} is an error term with a standard normal distribution conditional on $\mathbf{w}_{i,t-1}$ and $s_{i,t-1} = 1$. The conditioning on $s_{i,t-1} = 1$ ensures that only specialised dairy farms that survived up to time t-1 are considered in estimation.

In the medium term exit model exit is assumed to take place within three years after the decision to exit is taken. Therefore, not observing production in year t+3 is explained by information of year t-1. To this end we define the following index function for the medium term exit equation

$$s_{i,t+3} = \begin{cases} 1 \text{ if } \mathbf{w}_{i,t-1}'\boldsymbol{\gamma} + \upsilon_{it} > 0 & \text{(farmer decides to exit)} \\ 0 \text{ otherwise} & \text{(farmer decides not to exit)} \end{cases} \tag{5.8}$$

where $\boldsymbol{\gamma}$ is a parameter vector to be estimated and υ_{it} is an error term with a standard normal distribution conditional on $\mathbf{w}_{it}$ and $s_{i,t-1} = 1$. This means that $s_{i,t+3}$ selects the farms that do not produce milk at time t+3 out of the group of farmers that are producing milk at time t-1.

The set of explanatory variables in the selection equation ($\mathbf{w}_{i,t-1}$) contains the number of household members, age, age squared, the milk price index, the price index for other outputs the dairy cattle price index, the index for wages in the agricultural sector in The Netherlands, on-farm labour, a discrete variable indicating the level of education of the farm manager, the number of hectares a farm owns, a dummy indicating whether a farm earns off-farm labour income, a dummy indicating whether a farm has sheep, a dummy indicating whether a farm has pigs, a dummy indicating whether a farm grows crops and a dummy indicating whether a farm keeps cattle for meat. The dummies for the activities of farmers next to milk production are chosen such that at least 15 per cent of all farmers in the data set perform the activity. The price and income variables are divided by the price index of a composite of variable inputs to impose homogeneity of degree zero in these variables.

The exogeneity assumption for the number of household members, the age variables, education level and the wage and price indices are easy to defend since these can not be changed on the short run by individual farmers. Farmers that stop milk production are almost all farmers that already have other activities. Therefore, we assume the exogeneity assumption on the dummies for other activities is justified. Four out of five farmers that stop milk production do stay in agriculture. This means that inputs like land and labour stay on the farm. For this reason we also assume the exogeneity assumption on these variables is justified. Unfortunately, it is not possible to test the exogeneity assumptions. For this test we need instruments. These have to be uncorrelated with the error terms in (5.7) and (5.8) and correlated with the variables of which the exogeneity is tested. Often lagged values of the variables under investigation are used as instruments. However, by the way we construct our dependent variable we implicitly claim that the decision to stop producing milk is not made at the moment milk production is actually stopped, but sometime in the years before that. This means that lagged values of the variables under investigation are also possibly endogenous with respect to v_{it}. This makes them unsuitable as instruments. The data sets at our disposal do not provide other suitable candidates for instruments.

5.3.2 Growth

Next to the survival model we want to estimate a growth of individual milk production equation. In the theoretical growth section 5.2.2 it is reasoned that growth in milk production is a continuous adjustment to both optimise profit and utility of the farm household. Growth therefore depends on the elements that influence farm profit and on other income next to farm profit. All these elements are used as explanatory variables in the following empirical equation:

$$y_{it} = \alpha y_{i,t-1} + \mathbf{x}_{it}'\boldsymbol{\theta} + c_i + \varepsilon_{it} \tag{5.9}$$

where y_{it} is the size of farm i at time t, $\mathbf{x}_{it}$ is a vector of explanatory variables, c_i is an unknown farm specific effect, ε_{it} is an error term and α and $\boldsymbol{\theta}$ are parameters to be estimated. For y_{it} we use milk quota in kilograms. This represents the size of the dairy part of the farm, not the size of the whole farm. Subtracting $y_{i,t-1}$ from both sides of (5.9) gives a structural growth equation.

The dependent variable in this model is the amount of milk production in kilograms. The vector of explanatory variables contains three groups. The first is a group of factor inputs including land, buildings, machinery and labour. The second is a group of farm price indices including the quota price index, the other output price index and the cattle price index. The third is a group of off-farm incomes including off-farm labour income and external non-labour income. The decision to grow in the main farming activity (milk) is likely to be made together with choices on the amount of factor inputs and off-farm incomes. This means that all these variables might be endogenous in the structural growth equation. We test for the exogeneity of these variables in the estimation section.

5.4 Data

We make use of two data sets that are available for Dutch agriculture. The main data set is constructed by the LEI and contains annual observations of a large number of variables for a sample of Dutch dairy farms. Every year part of the farms leaves the sample and is replaced with new farms. Keeping track of data for a long time can influence farmers' behaviour, because the knowledge on their own farm is increased. Replacing farms after a few years circumvents this problem. This results in a rotating panel data set.

Most of the farms leaving the rotating panel data set are leaving because of the reason explained above. However it is also possible that a farm leaves the dairy farms data set because it exits from milk production. It is not possible to determine whether a farm leaves the set based on statistical reasons or because of exit from milk production. For this we use another data set.

The other data set at or disposal contains annual information on all farms in The Netherlands that have a positive number of dairy cows in the year the data refer to or in the year before, however only on a limited amount of variables. One of the variables in this data set is the number of dairy cows. Since a dairy cow is a necessary requirement for producing milk, we conclude that a farm that does not have dairy cows does not produce milk. With this variable we can establish whether a farm that leaves the rotating panel data set exits milk production. This set contains data up to and including 2001.

The LEI creates a measure of the size of farms that is called the Dutch size unit[3]. This measure makes it possible to compare the size of farms that perform different activities. The size of a farm is the sum of the sizes of the different activities performed on the farm. This makes it possible to derive the relative size of each activity performed on a farm. With the help of this measure, a farm is classified to be a specialised dairy farm if the size of the dairy part of the farm is more than 50 per cent of the total size of the farm. The rotating panel data set containing Dutch specialised dairy farms consists of 6338 observations on 1307 farms. The period investigated is from 1987/88 until 1999/00.

The size of the milk production activity is expressed in kilograms of quota. The number of dairy cows in a certain year is measured on the first of May of that year. Next to the cows that are actually producing milk at the first of May it contains the cows that are out of the lactation period. Land is measured as the total area of farmland in hectares. The implicit quantities of buildings and machinery are obtained by dividing the total values of these variables, by their corresponding Tornqvist price index. The price indices are constructed using the available farm level prices from the LEI data set. If the farm level prices are not available price indices from CBS/LEI (2000) are used. 1991 is the base year for these and subsequent indices. Labour consists of total household labour measured in hours.

Price variables, influencing short-term farm income, are the milk price index, a Tornqvist price index for variable input, the price index for cattle, and a Tornqvist price index for other output. Variable input contains, amongst others, feed and veterinary costs. Cattle consist of cows aged one year and older. Other output contains marketable crops, veal, pigs, poultry and other farm revenues. Sheep, pigs, and meat cattle are expressed in number of animals. For sheep and pigs this includes both young and old animals. For pigs this includes both meat and breading animals. Arable crops is expressed in hectares. The dummies for off-farm labour,

[3] For readers familiar with the LEI data set: this variable is the size in nge. An nge is based on the value added per unit of output. See CBS/LEI (2006) for a definition.

sheep, pigs, meat cattle and arable crops have value one if a farm is engaged in the corresponding activity. The quota price index is based on the average quota price per year.

Off-farm labour income is the total labour income earned off-farm of the owners of the farm and their partners. Off-farm wage is represented by the national index of wages for agricultural hired labour. External non-labour income is a monetary value. It includes, amongst others, income from externally allocated capital and income from social benefits. Household variables used are the number of household members and a discrete variable indicating the education level of the head of the household. The age variable represents the age of the head of the household. In table A1 in Appendix 5.A an overview of the units, mean and standard deviation of the variables used is given.

5.5 Estimation

The procedures to estimate the empirical models for exit and growth, described in section 5.3, are explained in this section.

5.5.1 Exit

In this section we explain the choice of estimation method for the exit models of section 5.3.1. Since the rotating panel data set is used to construct $\mathbf{w}_{i,t-1}$, we can only use the farms that are in this set in estimation. In the specification of equation (5.7), a farm exits if the exit occurs at the same time as the farm is leaving the rotating panel data set. This does not happen very often and makes the share of exits in the total number observations in (5.7) extremely limited. This can have consequences for the statistical significance of the explanatory variables. A way to increase the share of exits in the number of observations used in estimation is to reduce the total number of observations by considering only the last observation of each farm in the rotating panel data set. As a consequence the exit models described by equations (5.7) and (5.8) can be estimated by a cross-section probit estimation procedure (see e.g. Verbeek, 2004: 190-194). This has the disadvantage, compared to panel data techniques, of not taking unobserved farm specific effects into account. The advantage of a cross-section approach is that we can easily incorporate household characteristics that do not change over time like the number of household members or schooling. Using panel data techniques this is less straight forward and only possible if we assume the observed outcomes of preferences of farm households like the number of household members and time allocation independent of unobserved household preferences (see e.g. Verbeek, 2004: 373-377)[4]. The approach we use in estimation is a cross-section probit approach using the last observation of each individual.

Most of the explanatory variables in the exit equations (5.7) and (5.8) are derived from the rotating panel data containing data up to and including 1999/00. Exit of the farms in this data set is derived from the data set containing all Dutch dairy farmers containing data up to and including 2001. This means that we can create s_{it} for all farms in the rotating panel data set. $s_{i,t+3}$, however, can only be created for the farms that exit the rotating panel data set up to and including 1997.

5.5.2 Growth

An obvious condition of growth in milk production is that a farm survives in milk production. The fact that we use, amongst others, farm characteristics to explain survival in equation (5.7) and (5.8) shows that we assume that the surviving farms are not a random draw from the original dairy farm population. Not taking this into account can lead to attrition bias in the estimation of the growth equation (Wooldridge, 2002: 585-587). Wooldridge shows that attrition bias can be tested by adding an inverse Mills ratio to a rewritten version of (5.9). This inverse Mills ratio is based on the estimation of a version of (5.7) and (5.8) where the selection variable has value one at time *t* if more than half of the size of farm *I* is represented by the size of the dairy part of the farm at time *t* and value zero otherwise. A test on the significance of the parameter associated with the inverse Mills ratio is a test that has no attrition bias as a null-hypothesis. We performed this test and could not reject the null-hypothesis. For this reason we conclude that attrition does not bias the parameters in our growth model. Therefore, we describe the estimation of the growth model without further taking possible attrition bias into account.

The growth equation is a dynamic panel data model. To estimate this equation we use the dynamic panel data estimation technique of Arellano and Bond (1991) for a model with possibly endogenous variables. The Arellano and Bond estimator is a fixed effects panel data estimator that takes first differences of (5.9), resulting in

[4] Applying panel data binary choice models would have been difficult, even if we did consider multiple observations per farm. Panel data models either rely on the implausible assumption that unobserved farm specific effects are uncorrelated with the explanatory variables in the model (the random effects probit approach) or rely on the existence of entry next to exit (the fixed effects logit approach), which is extremely scarce in our data set and Dutch dairy farming as a whole. See Verbeek (2004: 373-377) for a discussion and description of panel data binary choice estimation.

$$\Delta y_{it} = \alpha \Delta y_{i,t-1} + \Delta \mathbf{x}_{it}'\boldsymbol{\theta} + \Delta \varepsilon_{it} \tag{5.10}$$

where Δ is the first difference operator. Note that the first differencing of (5.9) eliminates the farm specific effects c_i. The differencing of (5.9) does not affect the parameters, which therefore end up in (5.10). Differencing does take the fixed effects into account without the need to individually estimate them. Unfortunately, the first differencing also eliminates the time-invariant variables in the model like number of household members and education. As with the farm specific effect, the effects of these variables are taken into account by the first differencing. However, we are not able to distinguish their individual effect[5].

The Arellano and Bond estimator uses instrumental variables. To explain the instrument set used, it is convenient to divide the vector $\mathbf{x}_{it}$ into a vector with possibly endogenous variables $\mathbf{x}_{it}^{n}$ and a vector with assumed exogenous variables $\mathbf{x}_{it}^{x}$. For the endogenous variables and dependent variable we can use ($\mathbf{x}_{i,t-2}^{n}$, $\mathbf{x}_{i,t-3}^{n}$,…, $y_{i,t-2}$, $y_{i,t-3}$,...) as instruments. These are uncorrelated with ε_{it} even though the $\mathbf{x}_{it}^{n}$ are endogenous with respect to ε_{it}. The exogenous variables are uncorrelated with ε_{it} by definition. Therefore, we do not have to instrument them.

The Arellano and Bond (1991) estimator is based on the Generalised Method of Moments (GGM). The moment conditions based on the instruments explained above are

$$E(\mathbf{Z}_i'\Delta\boldsymbol{\varepsilon}_i) = \mathbf{0} \qquad \text{for } i = 1,...,N \tag{5.11}$$

where $\boldsymbol{\varepsilon}_i = (\varepsilon_{i3},...,\varepsilon_{iT})$, N is the number of farms in the data set, T is the number of periods in the data set and

$$\mathbf{Z}_i = \begin{pmatrix} y_{i1}' & \mathbf{x}_{i1}^{n}{}' & \cdots & \mathbf{0} & \mathbf{0} & \cdots & \mathbf{0} & \mathbf{0} & \Delta\mathbf{x}_{i1}^{x}{}' \\ \vdots & \vdots & & \vdots & \vdots & & \vdots & \vdots & \vdots \\ \mathbf{0} & \mathbf{0} & \cdots & y_{i1}' & \mathbf{x}_{i1}^{n}{}' & \cdots & y_{i,T-2}' & \mathbf{x}_{i,T-2}^{n}{}' & \Delta\mathbf{x}_{iT}^{x}{}' \end{pmatrix}. \tag{5.12}$$

[5] Arellano and Bond (1991) do introduce a possibility to get estimates of time-invariant effects under the assumption that the $\mathbf{x}_{it}$ are uncorrelated with c_i. We performed this estimation, but had to reject the assumption made.

Equations (5.11) and (5.12) describe moments for a balanced data set. The data set at our disposal is unbalanced.

The GMM estimator used to estimate the vector of unknown variables, $\boldsymbol{\beta} = (\alpha, \boldsymbol{\theta}')'$, is

$$\hat{\boldsymbol{\beta}} = \mathbf{Q}^{-1}\left(\sum_{i=1}^{N}\Delta\mathbf{W}_i'\mathbf{Z}_i\right)\left(\sum_{i=1}^{N}\mathbf{Z}_i'\Delta\hat{\boldsymbol{\varepsilon}}_i\Delta\hat{\boldsymbol{\varepsilon}}_i'\mathbf{Z}_i\right)^{-1}\left(\sum_{i=1}^{N}\mathbf{Z}_i'\Delta\mathbf{y}_i\right) \tag{5.13}$$

where N is the number of farms in the data set, $\mathbf{W}_i = (\mathbf{w}_{i3},...,\mathbf{w}_{iT})'$, T is the total number of time periods in the data set, $\mathbf{w}_{it} = (y_{i,t-1}, \mathbf{x}_{it}')'$ is a p × 1 vector of explanatory variables, $\mathbf{y}_i = (y_{i3},...,y_{iT})'$, $\boldsymbol{\varepsilon}_i = (\varepsilon_{i3},...,\varepsilon_{iT})'$,

$$\mathbf{Q} = \left(\sum_{i=1}^{N}\Delta\mathbf{W}_i'\mathbf{Z}_i\right)\left(\sum_{i=1}^{N}\mathbf{Z}_i'\Delta\hat{\boldsymbol{\varepsilon}}_i\Delta\hat{\boldsymbol{\varepsilon}}_i'\mathbf{Z}_i\right)^{-1}\left(\sum_{i=1}^{N}\mathbf{Z}_i'\Delta\mathbf{W}_i\right) \tag{5.14}$$

and $\hat{\boldsymbol{\varepsilon}}_i$ is created with a first step estimator of $\boldsymbol{\beta}$ using equations (5.13) and (5.14) without the term $\hat{\boldsymbol{\varepsilon}}_i\,\hat{\boldsymbol{\varepsilon}}_i'$. The approximate large sample variance for the estimator is:

$$\mathbf{V} = \mathbf{Q}^{-1} \tag{5.15}$$

In this research we have an unbalanced data set. If there is no observation for farm *i* at time *t*, its corresponding variables are zero in the equations above. To see whether the initial structure of the model is correct, we use Sargan's *J*-test of overidentifying restrictions (Hall, 2005: 47). If there are *q* moment conditions[6] and *p* parameters, there are *q* - *p* overidentifying restrictions. In Sargan's J-test:

$$J = \left(\sum_{i=1}^{N}\Delta\hat{\hat{\boldsymbol{\varepsilon}}}_i'\mathbf{Z}_i\right)\left(\sum_{i=1}^{N}\mathbf{Z}_i'\Delta\hat{\boldsymbol{\varepsilon}}_i\Delta\hat{\boldsymbol{\varepsilon}}_i'\mathbf{Z}_i\right)^{-1}\left(\sum_{i=1}^{N}\mathbf{Z}_i'\Delta\hat{\hat{\boldsymbol{\varepsilon}}}_i\right) \tag{5.16}$$

[6] This means that there are *q* instruments.

where $\hat{\hat{\boldsymbol{\varepsilon}}}_i$ is the vector of residuals created with $\hat{\boldsymbol{\beta}}$ of equation (5.13). The null hypothesis of this test is that the over-identifying restrictions hold, and hence that the initial structure of the model is correct. The test statistic has a χ^2_{q-p} distribution under the null-hypothesis.

In (5.12) we divide the explanatory variables in endogenous and exogenous variables. A test of exogeneity of an explanatory variable compares the J-test statistic of a model in which the variable is treated endogenous with a model in which it is treated exogenous. It is important to treat the other possibly endogenous variables as such in these two models. The test for endogeneity is a difference J-test (Hall, 2005: 153-161). The test statistic for this test is the difference between the J-tests of the two models. This test statistic is chi-squared distributed with degrees of freedom equal to the difference in the number of instruments between the two models.

The Arellano and Bond estimator has next to the general J-test in GMM estimation two other tests for the model specification. The test value for first order autocorrelation in the first differenced residuals (AR(1) test) should be significantly negative and the test for second order autocorrelation in the first differenced residuals (AR(2) test) should be insignificant. The interested reader is referred to Arellano and Bond (1991) for the reasoning behind these tests.

5.6 Estimation results

In this section we describe the estimation results for exit and growth of specialised Dutch dairy farms.

5.6.1 Exit

In this section the estimation results for the short and medium term exit models (5.7) and (5.8) are described. Table 5.1 gives the estimation results of a probit regression of $s_{i,t}$ and $s_{i,t+3}$ on the explanatory variables described in section 5.3.1.

Table 5.1: Probit estimation results for exit from dairy farming

	Short term exit		Medium term exit	
Explanatory variable	estimate	t-ratio	estimate	t-ratio
Number of household members	-0.17	-2.56**	-0.08	-2.23**
Age	-0.02	-0.33	0.15	2.82**
Age squared/100	0.03	0.40	-0.13	-2.47**
Milk price index	0.74	0.15	-5.56	-2.00**
Other output price index	-0.76	-0.34	1.41	0.97
Cattle price index	0.18	0.04	-7.31	-2.68**
Off-farm wage index	-1.68	-1.74**	0.90	0.07
External non-labour income in 100.000 Euro	-0.06	-0.05	-0.16	-0.24
On-farm labour in 1000 hours	-0.15	-1.40	-0.13	-2.19**
Education level	0.49	2.55**	-0.02	-0.19
Land in hectares	-0.01	-1.75**	-0.02	-3.61**
Off-farm labour income dummy	0.12	0.61	0.01	0.05
Sheep dummy	-0.37	-1.42	-0.14	-0.98
Pig dummy	-0.22	-0.83	-0.27	-1.74*
Crops dummy	0.03	0.14	0.02	0.17
Meat cattle dummy	0.34	1.74**	-0.00	-0.02
Constant	0.39	0.05	7.74	1.66*

*(**) significance at 10 per cent (5 per cent) significance level.

The number of household members has a negative effect on the probability to exit milk production in both models. This reflects the availability of a successor or at least labour force in the future. Age has a positive effect up to approximately 59 years and a negative effect afterwards on the decision to exit milk production in the medium term. This confirms the expectation that the exit probability of older farmers is larger. We do not find this for the exit decision in the short term. We also do not find an effect of farm prices on the exit decision in the short term. However, if the milk price decreases (increases) the probability to exit in the medium term increases (decreases). A lower (higher) milk price has a negative (positive) effect on farm income, and therefore increases (decreases) the exit probability. An increase in other output price can decrease the probability of exit for the whole farm including the milk production part because of the positive effect on income. On the other hand the relative increase of other output price compared to the milk price can make the farmer decide to focus on this other output, and exit from milk production. The insignificant parameter for the other output price on the medium term exit decision means that we can not conclude that one of these two effects is stronger. If cattle is seen as an input for milk production, the positive effect of the cattle price on the probability to exit in the medium term seems counterintuitive at first, since a higher cattle price decreases income from milk production in this case. However, cattle is also an output for dairy farmers. Cattle as output makes the positive sign plausible. In contrast to the farm prices, off-farm labour income has an effect in the short term and not in the medium term. In the short term an increase in off-farm labour income decreases the probability of exit. Apparently milk production can be maintained in the short term by the extra income from off-farm labour. However, in the medium term this effect disappears and the farm prices significantly affect farm exit something they do not do at the short term. External non-labour income does not have an effect on the probability to exit from milk production. On-farm labour has a negative effect on the probability to exit milk production in the medium term, but not on the short term. Apparently there is no immediate reaction to a change in labour supply, but a lagged reaction. The negative effect of on-farm labour on exit reflects the possibility to maintain the labour intensive milk production activity. The level of education has a positive effect on the probability to exit in the short term but not in the medium term. The size of a farm expressed in land has a negative effect on the exit probability. This could indicate scale effects in the earning capabilities in the milk sector. The dummies for off-farm labour and other farm activities are included to see whether the probability to exit from milk production is influenced by the fact that there is already income on the farm from other activities. There are two possible ways of reasoning. The first is that having an income source next to income from milk production spreads the risk for the total household income. This means that a milk producing farm can level off occasional bad results from milk production with the other income sources. This process makes exit from milk production less likely. The second reasoning is that if a farm already has an income source next to income from milk production, it is easier to completely switch to that other income source. Based on this reasoning, having another income source, increases the probability to exit milk production. Having meat cattle has a positive effect on exit in the short term. Apparently meat cattle is a candidate sector to switch to after exit from milk production. In the medium term the dummy for keeping pigs is significantly different from zero. It has a negative value indicating that for pig production the risk spreading reasoning above is more likely in the medium term.

5.6.2 Growth

In this section we present the estimation results for the growth equation. The growth equation is equation (5.9) in the estimation section.

First we test for the exogeneity of the factor inputs land, buildings, machinery and labour and the off-farm income sources off-farm labour income and external non-labour income with the difference J-test explained in the estimation section. The test does not reject exogeneity for all variables except external non-labour income. Therefore we have to treat external non-labour income as endogenous in estimation. The endogeneity of external non-labour income can be explained by the fact that milk is produced under a quota system. To increase production quota has to be bought or leased. This limits the opportunity to allocate capital outside the farm. Income earned by allocating capital outside the farm is an element of external non-labour income.

From equation (5.12) in the estimation section follows that the Arellano and Bond (1991) estimator uses all available lags of the dependent variable in the instrument matrix. In our estimation this leads to near singularity problems in estimation. Limiting the lags of the dependent and endogenous variables used as instruments solves this near singularity problem. The question is now how much we should limit the lags used.

The J-test statistic mentioned in section 5.2 goes together with a probability that the overidentifying restrictions are not equal to zero and hence rejected. The model with values used up to 3 lags is the model with the lowest probability to reject the overidentifying restrictions. Therefore we choose this model as our preferred model[7]. The parameter values and parameter inferences of the models using values for instruments up to 2 and 4 lags do not statistically differ from the parameter values in our preferred model. In other words the estimation results are robust with respect to the number of lags used in the instrument matrix.

Table 5.2 gives the estimation results of the structural growth equation.

Table 5.2: Structural growth equation estimation results

Dependent variable: quota in kg	Estimate	t-ratio
lagged quota in kg	1.05	11.03**
Factor inputs		
Land	0.21	3.07**
Buildings	0.38	2.21**
Machinery	-0.11	-0.09
Labour	0.67	2.59**
Farm prices		
other output price	0.32	2.40**
cattle price	0.45	0.15
quota price	0.30	2.55**
Income		
off-farm labour income	0.14	0.15
external non-labour income	-0.35	-1.72*
J-test statistic		46.46
Degrees of freedom (*df*)		40
Probability $\chi^2_{df} > J$		0.78
t-ratio AR(1) test		-5.61
t-ratio AR(2) test		0.42

*(**) significance at 10 per cent (5 per cent) significance level.

[7] Models using values of the dependent and explanatory variables up to three lags are also used to perform the exogeneity tests discussed above. Using values up to 2 and 4 lags did not change the test results.

The estimated growth model has a J-test statistic of 46.46, which does not exceed the 10 per cent critical value of the χ^2_{40} distribution (51.81). Therefore, the model is not rejected on the basis of this test. The t-ratio for the AR(1) test is -5.37 and therefore significantly negative. The t-ratio for the AR(2) test is 0.76 and therefore not significantly different from zero. Therefore our model is also not rejected on the basis of the AR tests and the parameter estimates can be interpreted.

The parameter associated with lagged quota has value 1.05 and a t-ratio of 11.03 for a test with the null-hypothesis that the parameter is zero. However, to interpret the model as a growth model one should subtract lagged quota (or $y_{i,t-1}$ in terms of equation (5.9) in the estimation section) from both sides of the model. In this case 1.05 – 1 = 0.05 gives an indication of the dependence of the growth of quota ($y_{it} - y_{i,t-1}$) on the original size of quota ($y_{i,t-1}$). The positive sign suggests that relatively large farms grow faster than smaller farms, however the t-ratio for this number is 0.53 and the test whether it is statistically equal to 0 is not rejected at the 10 per cent level. This leads us to the conclusion that there is no evidence for the dependence of growth on the level of milk quota[8].

The possession of relatively large amounts of the factor inputs land, buildings and labour has a positive effect on growth in quota. This is not surprising since a relatively large amount of these makes it easier to incorporate the extra quota in the farming process.

Other output price has a positive effect on growth in quota. This is a counterintuitive result, since it is expected that if the returns to other output increase more production factors are allocated to this other output at the expense of milk production. This clearly does not happen. Probably dairy farmers use the increased income in other parts of the farm to increase their core activity, which is milk production. The positive effect of the quota price on growth could be counterintuitive. To increase milk production acquiring of quota is needed. Therefore, a quota price increase is expected to decrease the demand for quota. However, acquiring quota is an investment that has an earning capacity. This earning capacity is reflected in the quota price. In this way the quota price reflects the profitability of milk production, which makes the positive effect of quota price on growth plausible. Next to that, farmers might see quota partly as a speculative asset. When prices go up they are building up expectations and might be more willing to extend their quota.

[8] This result is closely related to Gibrat's law. However, Gibrat's law is tested in a double log model in which the proportionate growth dependence on size is tested. Unfortunately, the double log functional form was rejected in our case.

External non-labour income has a negative effect on growth. This is in line with its endogeneity. External non-labour income is partly a reflection of capital allocated off-farm. The endogeneity of external non-labour income shows that decisions on the on-farm or off-farm allocation of financial capital are made simultaneously. In this line of reasoning, a plausible explanation of the negative sign of external non-labour income on growth reflects the fact that capital allocated off-farm can not be used to acquire quota. Another explanation of the negative effect of external non-labour income on growth can be that the increased household income reduces the need to increase farm income by growth of milk production. The fact that we do not find this income effect for off-farm labour income makes this explanation less plausible.

5.7 Policy simulations

In this section we simulate the effects on exit and growth in Dutch dairy farming of the implementation of the 2003 CAP reform (European Commission, 2003). The reform entails a reduction in intervention prices for skimmed milk powder of 15 per cent (in three yearly steps of 5 per cent from 2004 to 2006) and 25 per cent for butter (three yearly steps of 7 per cent from 2004 to 2006 and 4 per cent in 2007). These reductions are expected to reduce the milk price farms receive and therefore farm income. To compensate for the loss in income direct income payments in three yearly steps are introduced. At the end of the implementation period they equal 35.5 Euro per ton of milk production. In the implementation period the direct income payments are coupled to production. After that they are decoupled. In addition, a prolongation of the milk quota system until 2014/15 was agreed, in combination with a milk quota increase of 1.5 per cent in three yearly steps of 0.5 per cent starting in 2006.

Here we do not claim to predict actual effects on exit and growth of the 2003 CAP reform. We calculate the effects as if the 2003 CAP reform would have been implemented in 1999/00 in three yearly steps. Moreover, we do not take into account the milk quota increase. The reason is that we lack information on the development of the exogenous variables.

We use equations (5.8) and (5.10) in the simulations. If the probability to exit is larger than 0.5 we consider a farm to exit milk production. We start the simulations with the actual growth between 1998/99 and 1999/00, the last years for which we have data. In the simulation we assume a milk price reduction of 15 per cent for farmers at the end of the policy reform. This is considered by Jongeneel, et al. (2005) as the most probable estimate for The Netherlands given the market situation. Ooms and Peerlings (2005) show that if the milk price decreases with a certain percentage, the price of the quota decreases with twice this percentage (see equation (5.6) for the relationship between both prices). Therefore, we simulate the effects of a milk price decrease by decreasing the quota price by twice the expected milk price decrease in the different scenarios.

We do not take into account that total milk production should not exceed the national quota amount. Although we calculate for each individual farm in the sample the policy effects, we only present average changes of the total milk production from year to year and over the whole simulation period. During the simulation we keep all other variables at their 1999/00 level except age in the exit model, since this is obviously increasing by one every year.

In the scenarios we look at the effects of the 2003 CAP reform as described and the effect of decoupling direct income payments already in the implementation period. We calculate the effects of the following scenarios:

S1: No policy change.

S2: Temporarily coupled direct income payments. The milk price decreases with 15 per cent in three steps of 5 per cent in the first three years of the simulation. These years the direct income payment is coupled to production. As a result the direct income payment in these years lowers the effective milk price decrease. At a milk price of 326.70 Euro per ton in 1999, the direct income payment of 35.50 Euro per ton at the end of the policy reform is 10.86 per cent of the milk price. So with coupled direct income payments the milk price decrease is 4.14 per cent instead of 15 per cent at the end of the policy reform. This is 1.38 per cent per year in the first three years. After the third year the direct income payment is decoupled from actual production. Therefore, from year four on the milk price is decreased by 15 per cent (compared to its value at the start of the policy reform) and external non-labour income is increased by 35.50 Euro per ton of production in year 3. As mentioned before, the milk price decrease is simulated by decreasing the quota price with twice the percentage change of the milk price.

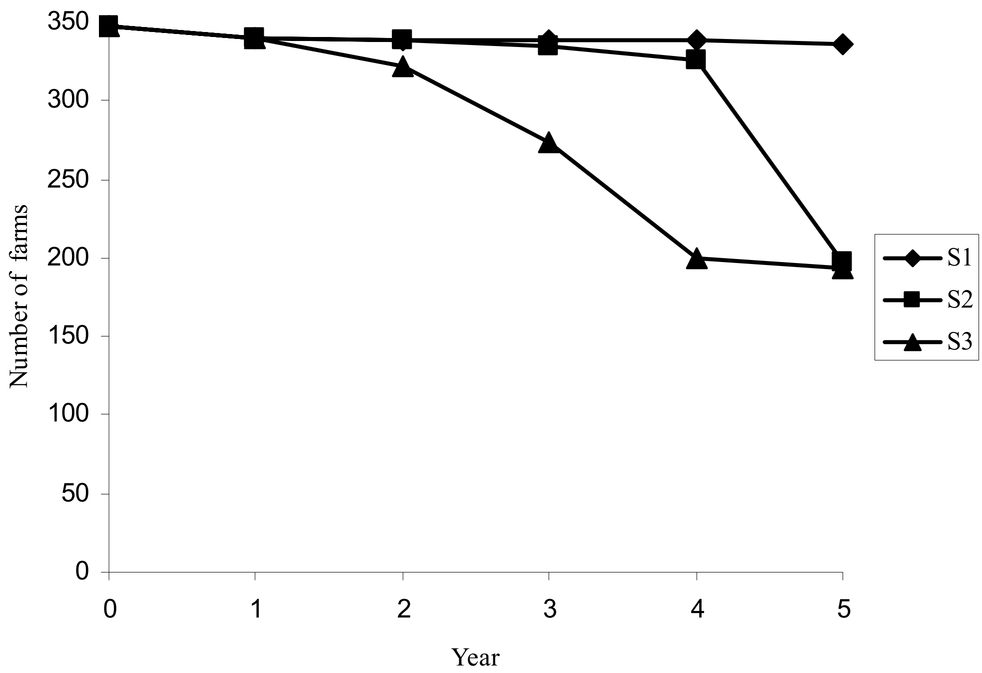
S3: Completely decoupled direct income payments. The milk price decreases with 15 per cent in three steps of 5 per cent in the first three years of the policy reform and remains 15 per cent from year four on. The decoupled direct income payment is simulated by increasing external non-labour in three equal steps to reach 35.50 Euro per ton of production in 1999 from year three on. It is explained above that this is simulated by decreasing the quota price with twice these percentages.

The simulation results are given in Table 5.3 and Figure 5.1 below.

Table 5.3: Percentage growth of total milk production from year to year and in total and the number of exits for the different scenarios.

	Year 1	Year 2	Year 3	Year 4	Year 5	Total	Exits
S1	4.02	4.96	4.95	4.94	4.97	26.22	12 of 348
S2	3.82	4.39	4.12	1.53	-20.75	-9.20	151 of 348
S3	3.30	1.07	-5.73	-15.32	-1.85	-18.20	154 of 348

Figure 5.1: Number of farms in the different scenarios



In S1 the growth in total milk production is close to 5 per cent per year except for the first year where it is about 4 per cent. The small difference between the first year and the other years is caused by the fact that part of the farms in the year 1999/00 are expected to exit based on the individual values of the explanatory variables in the exit model in 1999/00. After that year the variables in the exit model do not change from year to year except age, which causes some farm exits. Therefore, after year 1 the remaining farms have a rather constant growth.

In the temporarily coupled direct income payment scenario (S2) the growth of total milk output is slightly lower in year one compared to S1. This is caused by the first step of the effective milk price decrease. Because of the second step in milk price decrease and the exits caused by the first step the difference in growth in year two is slightly bigger than in year one. The same holds for year three compared to year two. The growth in difference with S1 in year four compared to year three is caused by the exits in year three and the fact that direct income payments become decoupled in year four. This causes 39.57 per cent of farms to exit in year five (see Figure 5.1). As a result total milk production suddenly drops by 20.75 per cent. This shows that the relatively small farms drop out of production. The large drop in production in year five causes the large drop in total milk production over the whole period simulated.

In S3 the decrease is more gradual over the years than in S2. Moreover, in S3 the decrease starts earlier. This is caused by larger milk price decreases during the policy implementation period, since these are not partially compensated by the coupled direct income payments. The larger milk price decreases during the policy implementation period in S3 cause more farmers to exit during the implementation period (Figure 5.1) and has a more negative effect on the growth of remaining farms compared to S2. The early start of the decrease also causes an earlier start of cumulative effects of decreases in size. This explains why the decrease of total milk production over the whole period in S3 is twice as large as in S2. The cumulative effects in the simulation of growth are caused by the dynamic nature of the growth model. A change in production now influences future growth. The exit model is static and does not cause cumulative effects. Therefore, the number of exits is similar in both scenarios.

In S2 and S3 total milk production falls as a result of the decrease in quota price. The quota price is determined by the difference between the milk price and the shadow price of production (marginal cost of production) i.e. the profitability of quota. An underlying assumption in our simulations is a constant shadow price of production over the years. However, due to economies of scale effects caused by the growth of remaining farms and technological development, the shadow price of production might decrease. In this case we have overestimated the quota price decrease which leads to a stronger decrease in total milk production in our simulations than in practice. The conclusions drawn on the difference between the results of S1 and S2 remain valid, though.

5.8 Summary and conclusions

The purpose of this chapter is to estimate exit and growth models of Dutch dairy farms in order to make farm specific statements about the 2003 CAP reform. Exit is defined as stopping dairy farming. Farm growth is defined as the change in quota amounts (a reduction being negative growth).

Results indicate that the decision to exit dairy farming is largely determined by household characteristics as age and the size of the household. This result is often found in the farm exit literature; see e.g. Kimhi and Bollman (1999) and Glauben et al. (2004). Unfortunately it was impossible to incorporate other household characteristics as illness and divorce. One would expect that these variables also play an important role in the decision to exit farming in general. Variables determining the profitability of dairy farming, e.g. milk price, affect in the medium term the decision to exit. In the short term this effect is not found though. This is in contrast with e.g. Foltz (2004) who does find an effect of farm prices on the short term on the decision to exit. Farm growth, i.e. increasing the milk quota amount, is strongly influenced by the availability of production factors as labour, capital and land. This indicates that a relatively large production capacity results in a larger growth of production. To the best of our knowledge the effect of factor inputs on milk output growth has not been investigated before. Simulation results show that the 2003 CAP reform has a large negative effect on the number of farms. The remaining farms do grow, but not enough to circumvent a large negative effect on total milk production after the policy reform. The timing of the decrease in milk production differs whether the direct income payments are coupled or decoupled in the implementation period. Simulation results show that decoupling direct income payments in the implementation period results in a more gradual decrease of total milk production and number of farms compared to a situation where direct income payments are coupled in the implementation period. The total decrease in milk production is larger in the former though, because the earlier start of decrease in milk production has, next to the milk price decrease, an extra negative effect on milk production in succeeding years.

The analyses in this chapter are subject to some qualifications. First, data and estimation techniques did not allow taking unobserved farm specific effects and household characteristics as illness and divorce into account in the exit equation. Second, because the 2003 CAP reform is not yet fully implemented it not clear yet what the effect on the milk price and quota price will be. Finally, in the simulations we keep all variables except milk price, age and direct income payments constant while these variables do change over time and in some cases can be affected by the policy changes. The latter also holds for the quota price driving our simulations. Despite these caveats the exit and growth model can give valuable insights in the effects of the 2003 CAP reform. Especially farm exit as a result of policy changes has not been examined before for Dutch dairy farming.

Appendix 5.A: Data

Table A1: Data for average specialized dairy farm in the Netherlands in 1999/00

Variable	Unit	Mean	Standard deviation
Quota	1000 kg	472.59	286.01
Cows[a]	Number	54.12	30.58
Land	Hectares	35.26	19.82
Buildings	1000 Euro of 1999	198.48	110.52
Machinery	1000 Euro of 1999	81.95	54.55
On-farm labour	Hours	4068	1484
Milk price index	1991 = 1	0.92	
Other output price index	1991 = 1	0.90	
Input price index	1991 = 1	0.92	
Cattle price index	1991 = 1	0.87	
Quota price index	1991 = 1	1.07	
Sheep[a b]	Number	15.86	49.22
Pigs[a c]	Number	50.62	159.36
Meat cattle[a d]	Number	3.37	13.53
Arable crops[a e]	Hectares	6.11	8.08
Off-farm labour income[a f]	1000 Euro	5.09	7.77
External non-labour income	1000 Euro	10.29	8.82
Off-farm wage index	1991 = 1	1.24	
Household members	Number	4.65	1.91
Education	Discrete variable	2.45	0.60
Age	Years	49.61	10.670

[a] The characteristics of these data are based on 27839 observations in 1999 of specialised dairy farms in the data set containing all farms in The Netherlands. The characteristics of the other variables, except the price variables, are based on the 357 observations in 1999 of specialised dairy farmers in the rotating panel data set of the LEI.

[b] The number of sheep is positive for 22.4 per cent of observations.

[c] The number of pigs is positive for 22.1 per cent of observations.

[d] The number of meat cattle is positive for 28.1 per cent of observations.

[e] The number of hectares of arable crops is positive for 54.2 per cent of observations.

[f] Off-farm labour income is positive for 46.2 per cent of observations.

Chapter 6 Discussion and conclusions

The general objective of this thesis is to estimate models based on a household production model for Dutch dairy farms producing under a quota regime. This is done using panel data and GMM, keeping account of special features in estimation like endogeneity, sample selection and unobserved farm specific effects. The estimated models are used to understand how Dutch dairy farms react on the 2003 CAP reform.

In this chapter we present and discuss the main outcomes of this research. Moreover, we give some suggestions for future research.

Milk production

In chapter 2 a production function for milk is estimated. The function is estimated with a Generalised Method of Moments (GMM) approach for linear panel data models allowing for endogenous variables. Determining the endogeneity or exogeneity based on tests within the GMM framework instead of ad hoc determination are a contribution to the literature of applied micro-economic models of agricultural production.

Milk production technology can be described both by a production function and a profit function. Both have been estimated before for Dutch dairy farming. Thijssen (1992, Chapter 2) estimated both profit and production models for a period before the introduction of the milk quota system in 1984. Helming et al. (1993) and Boots and Peerlings (1999) both estimated profit functions for a period before and after the introduction of the milk quota system. In this thesis we estimate a production function for a period after the introduction of the milk quota system. Thijssen (1992: 26) finds slightly increasing returns to scale in the pre-quota period and Boots and Peerlings (1999) find considerable returns to scale in the period after milk quota introduction. In this thesis almost constant returns to scale are found under the quota regime. Since the returns to scale measure is the sum of the production elasticities, the production elasticities found in this thesis also differ somewhat from those in the other researches. The main difference is the lower elasticity for land of 0.13 compared to about 0.30 in the other researches. The production elasticities for variables input and labour are slightly higher in this thesis.

Assuming profit maximisation shadow prices of fixed inputs can be derived from the estimated production function. Helming et al. (1993) show a decrease of the shadow price of land after the introduction of the quota system. In this thesis evidence is found for a continuation of this decrease. Helming et al. (1993) find the same effect for labour. A continuation of this effect is, however, not found in this thesis. The shadow price of labour in this thesis is comparable to that of Boots and Peerlings (1999).

Labour

In Chapter 3, reduced form labour supply equations for on- and off-farm labour are derived and estimated. Unfortunate, the LEI data set lacks distinction between male and female labour supply, which made it impossible to estimate gender specific labour supply equations. The data on off-farm labour caused two other challenges that could be dealt with. The first challenge is the lack of off-farm labour hour data. A contribution of this thesis to the literature is the derivation of an off-farm labour supply model in which correct effects of changes in explanatory variables are estimated using off-farm labour income instead of off-farm labour hours as dependent variable. The second challenge is the many zero observations for off-farm labour. This can cause sample selection bias in estimation. Semykina and Wooldridge (2005) developed a test for sample selection bias in panel data models allowing for the endogeneity of some of the explanatory variables. The new element in their work is that explanatory variables are allowed to be endogenous within the test procedure. This test is performed in this thesis and contributes hereby to the literature by translating new results of econometrics into applied micro-economic models. Based on this test we concluded the absence of sample selection bias in the off-farm labour supply equation. The reduced on- and off-farm labour supply equations are estimated with the Mundlak (1978) fixed effects approach using GMM. As opposed to standard fixed effects estimation, the Mundlak (1978) approach allows for the estimation of effects of time-invariant variables under slightly stronger assumptions. Compared to other estimation methods like Ordinary Least Squares (OLS) and Two Stage Least Squares (2SLS) GMM has the advantage of a simple test for the validity of the model. If the stronger assumptions of the Mundlak (1978) approach would be incorrect, the test in GMM would reject the model. Both estimated labour supply models are not rejected by the test. The time invariant variables included in the reduced on- and off-farm labour supply equations are the household variables education, the presence of a successor and the number of household members. In Chapter 3 it is explained that the estimate for the effect of education on labour supply is biased. The other household variables appeared to be more important in explaining on-farm labour than in explaining off-farm labour. This result is comparable to that of Elhorst (1994) in labour supply models for Dutch dairy farmers in the pre-quota period. In this thesis no evidence is found for an income effect on labour supply.

This thesis contributes to the literature of labour supply of Dutch dairy farmers by estimating effects on labour supply of other factor inputs and milk output. As expected, off-farm labour is substituted for on-farm labour if output increases. Furthermore, a positive effect of land on on-farm labour supply is found. This reflects the expected need for more on-farm labour on larger farms.

Investment

In Chapter 4, a theoretical Euler investment equation for factor inputs used in milk production is derived. This equation includes financial measures as explanatory variables. The idea of including financial variables in investment equations is not new. However, estimation of such models required a rather subjective separation of farms into financially constrained and financially unconstrained farms (see e.g. Hubbard and Kashyap, 1992; Whited, 1992 and Bond and Meghir, 1994). An interesting alternative approach was proposed by Van Ees et al. (1997 and 1998). They consider the interest rate in the Euler equation model to be farm-specific. This thesis contributes to the literature by replacing this farm-specific interest rate by an explanatory model including financial variables. The resulting model is estimated for investments in machinery on Dutch dairy farms using the GMM approach. Unfortunately, the small number of investments in buildings and land made it impossible to estimate these investment equations. Results show that the amount of buildings on a farm has a positive effect on investment in machinery whereas there is no evidence of an effect of the amount of land on investment in machinery. Elhorst (1994) finds the opposite for an investment in machinery model for Dutch dairy farmers for an earlier period. This could be an indication that the type of machinery purchased on Dutch dairy farms is shifting from machinery used on the land to machinery used in buildings, like milking installations. This thesis also finds evidence for the importance of the availability of labour to employ the machinery. This was also found by Elhorst (1994). In this thesis a first attempt is made to estimate the effect of financial variables on investment in machinery on Dutch dairy farms. Such an effect is not found. This differs from the findings of Kuiper and Thijssen (1996) who do find effects of financial variables on investment in Dutch agriculture. However, they look at total investment in factor inputs. This, together with the lack of evidence for an effect on investment in machinery in this thesis, could indicate that the effect found by Kuiper and Thijssen (1996) is driven by an effect of financial variables on investment in land and buildings, but not machinery. This is also suggested by the results of Elhorst (1993) who does find an effect of financial variables on the decision to invest in land and buildings, but not for machinery.

Benjamin and Phimister (2002) find mixed effects of financial variables on aggregate investment for British and French farmers. They conclude that the differences between France and Britain can be attributed to differences in financial markets. This makes general comparisons of farm behaviour between different countries difficult in the case of investments.

Growth and exit

In Chapter 5, exit models for the short and medium term and a growth equation for Dutch dairy farmers are formulated and estimated. A contribution of this thesis to the literature is that exit is not considered only as a short term decision. In the exit literature, a decision to exit given present information leads to an immediate exit. Next to this approach an exit model is derived in which a decision to exit given present information leads to exit in the medium term i.e. within three years. It appeared that fixed effects binary choice methods have data requirements that could not all be met by our data set. Therefore, a cross-section probit method is used to estimate both exit models. This approach does not take farm specific effects into account, but does allow for the estimation of parameters related to time-invariant variables. Another contribution of this thesis to the literature is that exit from a particular sector in agriculture (in this case milk production) is considered instead of total exit from farming. More land and a larger household reduce the probability of exit. There are however also considerable differences between the short and medium term exit models. The results of the medium term exit model are comparable with results of short term exit models in other researches (e.g. Kimhi and Bollman, 1999). However, one has to keep in mind that the number of short term exits is very small in our data set. This might influence estimation results. Results indicate that the decision to exit dairy farming is largely determined by household characteristics as age and the size of the household. This result is often found in the farm exit literature; see e.g. Kimhi and Bollman (1999) and Glauben et al. (2004). The structural growth equation is estimated with the approach of Arellano and Bond (1991), which is using GMM estimation. This is an often used estimation approach for dynamic panel data models (see e.g. Thijssen, 1992, Chapter 5). This thesis contributes to literature by determining explanatory variables in the individual farm growth model to be exogenous or endogenous based on exogeneity tests within the GMM framework. Another contribution to the literature is that the effects of factor inputs on growth in output are estimated. It is found that dairy farms that are endowed with a relatively large amount of factor inputs tend to grow faster. External non-labour income is found to have a negative effect on farm growth, but no effect on farm exits.

Policy

The models developed in this thesis are used to make some statements on the effect of the 2003 CAP reform on Dutch dairy farming. The reform entails a reduction in intervention prices and a small increase in milk quota. As a result income from farming decreases on average with 22 per cent when we assume that the milk price falls by 21 per cent. This has the consequence that 45 per cent of Dutch dairy farmers end up with a negative income from farming. To compensate for the income loss farms receive direct income payments. With these, still 31 per cent end up with a negative income from farming. The farms with a negative income from farming after income compensation are not equally distributed over different size classes. The percentage of small farms with negative income from farming is as much as 69 per cent if all farms remain in milk production. Considering total household income, 20 per cent of farms have a negative income after the 2003 CAP reform and 42 per cent of small farms. Apparently small farms have a relatively large off-farm income. These results are calculated without taking structural change in Dutch dairy farming into account.

However, the milk price decrease also increases the probability to exit milk production. Next to that the probability to exit milk production decreases if a farm is large in terms of land. This suggests that due to the milk price decrease the number of farms producing milk decreases and that it will be mainly the small farms that exit. This leaves possibilities for remaining farms to grow and take advantage of the better earning capabilities of being a large farm. In total the effect on income for the remaining farms is therefore expected to be less severe than calculated in a situation without structural change. Exits depend on the way direct payments are implemented. Simulation results show that decoupling direct income payments in the implementation period results in a more gradual decrease of the number of farms compared to a situation where direct income payments are coupled in the implementation period.

Decoupled direct income payments are argued by the WTO not to influence production decisions, because they do not alter relative prices (USDA, 2003). However, next to a price effect, decoupled income payments can have other effects on production decisions. In this thesis two possibilities are examined. First, the receipt of decoupled income payments has an effect on total income. If a change in income has an effect on labour supply, this income effect can influence production decisions through the supply of on-farm labour. Second, the receipt of direct income payments has an effect on financial variables of the farm household like e.g. solvability of liquidity. Financial variables can have an effect on capital investments, because banks base the borrowing capacity of farms on financial variables. If this is the case the introduction of direct income payments can influence production decisions in the long term. In this thesis there is no evidence found for both effects for Dutch dairy farmers. Direct income payments are not expected to influence production decisions on Dutch dairy farms through an income effect on on-farm labour supply. In contrast, El-Osta et al. (2004) find a positive effect of direct income payments on on-farm labour supply for US farms. The results in this thesis with respect to the effects of decoupled payments on off-farm labour are however comparable with the conclusions of El-Osta et al. (2004) and Goodwin and Mishra (2004) for US farms. Next to that, financial variables do not have a significant effect on investment in machinery. Therefore, decoupled income payments are not expected to have an effect on investment in machinery in case these payments would lead to changes in e.g. solvability or liquidity.

Model and data

This thesis uses a household production models as a conceptual framework. Empirically estimated models are needed to understand how Dutch dairy farms react to changes in policy. Unfortunately, full estimation of a household production model is not possible. Therefore, only models based on parts of a household production model have been estimated. In estimation a LEI panel data set is used. The data set contains specialised and non-specialised farms that produce milk. However, the estimation models require parameters that are equal among farms. Therefore, farms have to be homogeneous to a certain extent. For this reason, only data on specialised dairy farms are used in estimation. This could have influenced the results found. However, the farms used in estimation represent 95 per cent of all dairy cows in the Netherlands in 1999.

Estimation is always on historical data while policies are changing. This is not a problem if the historical data can reveal reactions of individual farms to the changes in policies. This is possible if the policy instruments remain the same or the changed policies can be translated in price changes. With the direct income payments a new policy instrument is introduced in Dutch dairy farming. Therefore, it is not possible to use historic reactions of farmers to direct income payments to assess their effects. However, the direct income payments change income. With the revealed reactions of farms to income changes statements about the effects of the introduction of direct income payments have been made.

Final conclusion

The micro-economic panel data models for Dutch dairy farms developed and estimated in this thesis are a flexible tool to understand the expected reactions of Dutch dairy farms on the 2003 CAP reform. They could be elements of a fully specified household production simulation model of Dutch dairy farms. Such a model could be used to analyse effects of future policy and institutional changes. An example of a possible simulation could be determining the effect of introducing a flat-rate for direct income payments.

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Summary

In The Netherlands, the dairy sector is the largest agricultural sub-sector based on both gross production value and number of farms. It is characterised by family farms in which large part of labour, management and risk bearing capital are supplied by the owner and his or her household. The dairy sector is highly regulated by the Common Agricultural Policy (CAP) of the EU. Within the CAP, milk production is limited since 1984 by farm specific quotas. The 2003 CAP reform, by introducing direct income payments, makes policies even more farm specific. To understand how individual family farms react to policy changes it is necessary to develop farm specific models. The general objective of this thesis is to estimate models based on a household production model for Dutch dairy farms producing under a quota regime. This is done using panel data and the generalised method of moments (GMM), keeping account of special features in estimation like endogeneity, sample selection and unobserved farm specific effects. The estimated models are used to understand how Dutch dairy farms react on the 2003 CAP reform. To reach the general objective, the following specific objectives are formulated:

1. Estimate the production function for milk avoiding the endogeneity problem by using GMM as estimation method and using the estimation to determine the economic effects of the EU 2003 dairy policy reform for individual dairy farms and dairy farming as a whole in the Netherlands (Chapter 2).
2. Determine the effect on on-farm and off-farm labour of decoupled payments as part of the 2003 CAP reform based on the estimation of reduced form on-farm and off-farm labour supply equations for Dutch dairy farmers using panel data estimation techniques and taking possible sample selection in the off-farm labour supply equation into account (Chapter 3).
3. Investigate the effect of financial variables on investment of Dutch dairy farmers, using an Euler equation approach in which financial variables are explicitly included in the optimality conditions for investments and see whether the 2003 CAP reform has an effect on investments through its effect on financial variables (Chapter 4).
4. Determine the characteristics of Dutch dairy farms that influence growth and exit using estimation techniques that take the dynamic nature of growth and the definite nature of exit into account and use these models to make statements about the effects of the 2003 CAP reform on growth and exit (Chapter 5).

Chapter 2 reports the estimation of a production function for Dutch dairy farms under a supply quota regime, using a GMM fixed-effect panel data estimator to take account of heterogeneity among farms. This estimator can handle the mutual dependence between production and inputs (endogeneity). Endogeneity of certain input variables is not assumed *ex ante* but rather is tested for. The first-order conditions for profit maximisation are used to determine demand for variable inputs and shadow prices of quasi-fixed inputs. The model was then used to determine the economic effects for Dutch dairy farming of the 2003 CAP reform.

Profit, excluding the direct income payments, decreases on average by 22 per cent when we assume that the milk price falls by 21 per cent and by over 15 per cent when the milk price falls by 15 per cent. A direct income payment of 35.5 €/tonne compensates for 53 and 72 per cent of the profit fall respectively. Profit declines relatively more for small dairy farms than for large dairy farms. Even with the direct income payments (and a price decrease of 21 per cent) nearly 69 per cent of all small dairy farms will have a negative income from farming. The percentage of small farms with a negative total income is 42.2 per cent. On average, these percentages are 31.1 per cent and 20.1 per cent respectively. These results show that the survival of many small dairy farms is threatened.

The main goal of chapter 3 is to determine the effect of the introduction of decoupled income payments on on-farm and off-farm labour. To this end we estimate reduced form on-farm and off-farm labour supply equations for Dutch dairy farmers using panel data estimation techniques and taking possible sample selection in the off-farm labour supply equation into account. All Dutch dairy farmers supply labour to their farm, however only about half of Dutch dairy farms supply labour off-farm. Estimation results are biased if these farms are not a representative sample of all dairy farmers. This is tested using a sample selection test for panel data allowing for endogenous variables in the estimated equation. The test leads to the conclusion that we can not reject the hypothesis that the farms supplying off-farm labour are a representative sample from the Dutch dairy farms' population. Therefore, we can use a linear panel data estimation approach for estimation of the off-farm labour supply equation as well as for the on-farm labour supply equation. The estimated equations are used to make statements about the 2003 CAP reform. Part of this reform is the introduction of decoupled payments.

Decoupled payments are advocated by the World Trade Organization (WTO) as a way to transfer income to farmers with minimal potential to distort production and trade. However, theoretically decoupled payments can have impact on production through an income effect changing on- and off-farm labour supply (USDA). We do not find such an effect of decoupled payments on both on- and off-farm labour supplies and therefore production.

In chapter 4 a new way of modelling the impact of financial variables on investment decisions is proposed. Advantages of this approach over existing approaches are that financial variables are explicitly incorporated in the theoretical framework instead of adding them *ex post* to the empirical Euler investment equations and that no subjective classification of firms believed to be financially constrained has to be made. The model is estimated using data on machinery investments of Dutch dairy farms. Based on the literature, solvability, liquidity and total amount of debt are included as financial variables.

The estimation results show that the included financial variables do not have a significant effect on investment in machinery. An explanation for this could be that farmers do not change their amount of debt when they invest in new machinery but finance these investments from savings from the current or previous year. An implication of this finding is that direct income payments as proposed in the 2003 CAP reform do not have an effect on investment in machinery in case these payments would lead to changes in e.g. solvability or liquidity.

The goal of chapter 5 is to estimate exit and growth models of Dutch dairy farms in order to make farm specific statements about the 2003 CAP reform. Exit is defined as stopping dairy farming. Exit is a binary choice: either a farm exits or it stays in milk production. Therefore binary choice models are used to describe exit decisions. In exit literature, a decision to exit given present information leads to an immediate exit. Next to this approach an exit model is derived in which a decision to exit given present information leads to exit in the medium term i.e. within three years. Farm growth is defined as the change in quota amounts (a reduction being negative growth). Farm growth is modelled using a dynamic panel data estimation approach.

Results indicate that the decision to exit dairy farming is largely determined by household characteristics as age and the size of the household. Variables determining the profitability of dairy farming, e.g. milk price, affect the decision to exit in the medium term. In the short term this effect is not found though. Farm growth, i.e. increasing the milk quota amount, is strongly influenced by the availability of production factors as labour, capital and land. This indicates that a relatively large production capacity results in a larger growth of production. Simulation results show that the 2003 CAP reform has a large negative effect on the number of farms. The remaining farms do grow, but not enough to circumvent a negative effect on total milk production after the policy reform, unless the marginal cost of milk production decreases. The timing of the decrease in milk production differs whether the direct income payments are coupled or decoupled in the implementation period. Simulation results show that decoupling direct income payments in the implementation period results in a more gradual decrease of total milk production and number of farms compared to a situation where direct income payments are coupled in the implementation period. The total decrease in milk production is larger in the former though due to cumulative effects.

Results described above show a decrease of income on Dutch dairy farms due to the milk price decrease as a result of 2003 CAP reform. These results are calculated without taking structural change in Dutch dairy farming into account. However, the milk price decrease also increases the probability to exit milk production. Next to that the probability to exit milk production decreases if a farm is large in terms of land. This suggests that due to the milk price decrease the number of milk producing farms decreases and that it will be mainly the small farms that exit. This leaves possibilities for remaining farms to grow and take advantage of the better earning capabilities of larger farms. In total the effect on income for the remaining farms is therefore expected to be less severe than calculated in a situation without structural change.

The micro-economic panel data models for Dutch dairy farms developed and estimated in this thesis are a flexible tool to understand the expected reactions of Dutch dairy farms on the 2003 CAP reform. They could be elements of a fully specified household production simulation model of Dutch dairy farms. Such a model could be used for analysing effects of future policy and institutional changes. An example of a possible simulation could be determining the effect of introducing a flat-rate for direct income payments.

Samenvatting

In Nederland is de melkveesector, op basis van zowel de bruto productiewaarde als het aantal bedrijven, de grootste subsector in de landbouw. Het wordt gekarakteriseerd door familiebedrijven waarin een groot deel van de arbeid, het management en het risicodragend kapitaal door de eigenaar en zijn of haar huishouden geleverd wordt. De melkveesector is in hoge mate gereguleerd door het Gemeenschappelijke Landbouwbeleid (GLB) van de Europese Unie. Hierbinnen is sinds 1984 de melkproductie gelimiteerd door bedrijfspecifieke quota. Door het introduceren van directe inkomenstoeslagen in de 2003 hervorming van het GLB, wordt beleid nog meer bedrijfspecifiek. Om te begrijpen hoe individuele familiebedrijven reageren op veranderingen in beleid is het noodzakelijk bedrijfspecifieke modellen te ontwikkelen. De algemene doelstelling van dit proefschrift is het schatten van modellen gebaseerd op een theoretisch huishoudproductie model voor Nederlandse melkveebedrijven die produceren onder een quotum regime. Dit is uitgevoerd met behulp van panel data en de Gegeneraliseerde Momenten Methode (GMM), waarbij rekening wordt gehouden met speciale situaties bij het schatten zoals endogeniteit, steekproef selectie en niet waargenomen bedrijfspecifieke effecten. De geschatte modellen zijn gebruikt om te begrijpen hoe Nederlandse melkveebedrijven reageren op de 2003 hervorming van het GLB. Om de algemene doelstelling te bereiken zijn de volgende specifieke doelstellingen geformuleerd:

1. Het schatten van de productiefunctie voor melk waarbij rekening wordt gehouden met de endogeniteit van verklarende variabelen door het gebruik van GMM als schattingsmethode en het gebruiken van de schattingen om het effect van de 2003 hervorming van het zuivel beleid binnen de GLB te bepalen voor individuele bedrijven en de Nederlandse melkveesector als geheel (Hoofdstuk 2).
2. Het bepalen van het effect van de introductie van ontkoppelde inkomenstoeslagen binnen de 2003 hervorming van het GLB voor het aanbod van gezinsarbeid op en buiten het bedrijf, gebaseerd op de schatting van gereduceerde vorm vergelijkingen voor beide soorten arbeidsaanbod van Nederlandse melkveebedrijven, gebruik makend van panel data en rekening houdend met mogelijke onzuiverheid veroorzaakt door de gebruikte steekproef in de vergelijking voor arbeid dat buiten het bedrijf aangeboden wordt (Hoofdstuk 3).
3. Het onderzoeken van het effect van financiële variabelen op investeringen van Nederlandse melkveehouders met een Euler vergelijking waarin financiële variabelen expliciet in de optimaliteitscondities voor investeringen opgenomen zijn en het bekijken

of de 2003 hervorming van het GLB een effect heeft op investeringen door hun effect op de financiële variabelen (Hoofdstuk 4).

4. Het bepalen van de karakteristieken van Nederlandse melkveebedrijven die de productiegroei en productiebeëindiging beïnvloeden gebruik makend van technieken die rekening houden met de dynamische aard van productiegroei en het definitieve karakter van productiebeëindiging en het gebruiken van de geschatte modellen om uitspraken te doen over het effect van de 2003 hervorming van het GLB op productiegroei en productiebeëindiging (Hoofdstuk 5).

Hoofdstuk 2 beschrijft de schatting van een productiefunctie voor Nederlandse melkveebedrijven producerend onder een melkquotum, waarbij gebruik wordt gemaakt van een GMM panel data schatter om rekening te houden met mogelijke endogeniteit van de verklarende variabelen en heterogeniteit tussen verschillende bedrijven De endogeneteit van verschillende variabelen is niet van te voren bepaald maar afgetest binnen het model. De eerste orde condities voor winstmaximalisatie zijn gebruikt om de vraag naar variabele productiefactoren en de schaduwprijzen van vaste productiefactoren te bepalen. Het model is vervolgens gebruikt om de economische effecten van de 2003 hervorming van het GLB voor de Nederlandse melkveesector te bepalen.

Winst, exclusief de directe inkomenstoeslagen, daalt gemiddeld met meer dan 22 procent als we aannemen dat de melkprijs met 21 procent daalt en met bijna 16 procent als de melkprijs met 15 procent daalt. Een directe inkomenstoeslag van €35.50 per ton compenseert de winstval met respectievelijk 53 en 72 procent. Winst daalt relatief sterker voor kleine bedrijven dan voor grote bedrijven. Zelfs met de directe inkomenstoeslagen (en een melkprijsdaling van 21 procent) zullen bijna 69 procent van alle kleine melkveebedrijven een negatief inkomen uit hun bedrijf krijgen. Het percentage kleine bedrijven met een negatief totaal inkomen is 42.2 procent. Gemiddeld voor alle bedrijven zijn deze percentages respectievelijk 31.1 en 20.1. Dit resultaat toont aan dat het overleven van veel kleine bedrijven bedreigd wordt.

De belangrijkste doelstelling van hoofdstuk 3 is het bepalen van de gevolgen van het introduceren van ontkoppelde inkomenstoeslagen voor het aanbod van arbeid op en buiten het bedrijf. Hiertoe hebben we gereduceerde vorm vergelijkingen voor beide soorten arbeidsaanbod geschat voor Nederlandse melkveehouders gebruik makend van panel data schattingstechnieken en rekening houdend met mogelijke verstoringen van de schatting van de aanbodvergelijking voor arbeid buiten het bedrijf door de in de schatting gebruikte steekproef. Op alle Nederlandse melkveebedrijven werken leden van het huishouden op het eigen bedrijf, maar slechts ongeveer de helft van de huishoudens biedt arbeid buiten het bedrijf aan. Schattingsresultaten zijn onzuiver als deze melkveebedrijven niet een representatieve steekproef van alle melkveebedrijven zijn. Hiervoor wordt getest binnen een model waarbij wordt onderkend dat een aantal variabelen mogelijk endogeen is. De test leidt tot de conclusie dat we de hypothese niet kunnen verwerpen dat de melkveebedrijven waar arbeid buiten de boerderij aangeboden wordt een representatieve steekproef van alle Nederlandse melkveebedrijven is. Daarom kunnen we lineaire panel data schattingstechnieken gebruiken voor zowel de vergelijking voor arbeid aangeboden buiten het bedrijf als voor de vergelijking voor arbeid aangewend op het bedrijf. De geschatte vergelijkingen zijn gebruikt om uitspraken te doen over de 2003 hervorming van het GLB. Een deel van deze hervormingen is het introduceren van ontkoppelde inkomenstoeslagen.

Ontkoppelde inkomentoeslagen worden door de Wereld Handelsorganisatie (WHO) bepleit als een manier om inkomen aan boeren over te dragen met een minimale kans op het verstoren van productie en handel. Maar theoretisch kunnen ontkoppelde inkomenstoeslagen gevolgen hebben op productie door middel van inkomenseffecten op zowel arbeid op het bedrijf als buiten het bedrijf. We hebben echter geen effect gevonden van ontkoppelde inkomenstoeslagen op zowel het aanbod van arbeid op als buiten het bedrijf.

In hoofdstuk 4 wordt een nieuwe manier voorgesteld voor het modelleren van het effect van financiële variabelen op investeringen. Voordelen van deze benadering, vergeleken met bestaande benaderingen, zijn dat financiële variabelen expliciet in het theoretische raamwerk geïncorporeerd worden in plaats van ze achteraf in een empirische Euler vergelijking toe te voegen en dat er geen subjectieve classificatie van bedrijven in financieel beperkte en financieel onbeperkte bedrijven gemaakt hoeft te worden. Het model is geschat met gebruik van gegevens van investeringen in machines van Nederlandse melkveebedrijven. Gebaseerd op de literatuur zijn solvabiliteit, liquiditeit en de totale hoeveelheid schuld als financiële variabelen in het model opgenomen.

De schattingsresultaten laten zien dat de toegevoegde financiële variabelen geen significant effect hebben op investeringen in machines. Een verklaring hiervoor kan zijn dat melkveehouders de hoeveelheid schuld niet veranderen wanneer er in machines geïnvesteerd wordt, maar dat deze investeringen worden gefinancierd met besparingen in het huidige of vorige jaar. Een implicatie van deze bevinding is dat directe inkomenstoeslagen, zoals voorgesteld in de 2003 hervorming van het GLB, geen effect hebben op investeringen in machines in het geval dat deze toeslagen tot veranderingen in bijvoorbeeld solvabiliteit en liquiditeit leiden.

Het doel van hoofdstuk 5 is het schatten van modellen voor productiebeëindiging en productiegroei op Nederlandse melkveebedrijven om bedrijfspecifieke uitspraken te doen over de gevolgen van de 2003 hervorming van het GLB. Productiebeëindiging is gedefinieerd als het stoppen met het produceren van melk. Beëindiging is een binaire keuze: of de productie wordt beëindigd of de boerderij blijft melk produceren. Daarom wordt een binair keuze model gebruikt om productiebeëindiging te beschrijven. In de literatuur leidt een beslissing om productie te beëindigen, gegeven de huidige informatie, tot een onmiddellijke beëindiging van productie. Naast deze benadering is er een model afgeleidt waarbij een beslissing om productie te beëindigen, gegeven de huidige informatie, tot een daadwerkelijke beëindiging binnen een middellange termijn (drie jaar) leidt. Productiegroei is gedefinieerd als het verschil in quotum hoeveelheden (hierbij is een afname negatieve groei). Het productiegroeimodel is geschat met behulp van een dynamisch panel data schattingsbenadering.

Resultaten geven aan dat de beslissing om te stoppen met melkproductie grotendeels bepaald wordt door huishoudkarakteristieken als leeftijd van het hoofd van het huishouden en de grootte van het huishouden. Variabelen die de winstgevendheid van melkproductie bepalen, zoals de melkprijs, beïnvloeden de beslissing om op middellange termijn productie te beëindigen. Dit effect wordt echter niet gevonden voor de onmiddellijke productiebeëindiging. De groei van melkproductie wordt sterk beïnvloed door de beschikbaarheid van productiefactoren zoals arbeid, kapitaal en grond. Dit geeft aan dat een relatief grote productiecapaciteit tot een grotere productiegroei leidt. Simulatieresultaten laten zien dat de 2003 hervorming van het GLB een sterk negatief effect heeft op het aantal melkveebedrijven. De overblijvende boerderijen vergroten hun productie wel, maar niet genoeg om een negatief effect op de totale Nederlandse melkproductie te voorkomen. Tenzij de marginale kosten van melkproductie dalen. Het tijdspad van de afname van melkproductie en aantal melkveebedrijven hangt af van de wijze waarop directe inkomenstoeslagen worden geïntroduceerd. Simulatieresultaten laten zien dat het ontkoppelen van directe inkomenstoeslagen in de periode dat ze geleidelijk worden geïntroduceerd resulteert in een meer geleidelijke afname van de totale melkproductie en het aantal melkveebedrijven in vergelijking met een situatie waarin directe inkomenstoeslagen tijdens de introductie aan melkproductie gekoppeld worden. In het eerste geval is de afname van totale productie echter groter door cumulatieve effecten.

Zoals beschreven daalt het inkomen op Nederlandse melkveebedrijven als gevolg van de 2003 hervorming van het GLB. Dit resultaat is berekend zonder rekening te houden met structurele veranderingen in de Nederlandse melkveesector. Echter, de dalende melkprijs verhoogt ook de kans dat een melkveebedrijf stopt met melkproductie. Daarnaast neemt de kans dat een melkveebedrijf stopt met melkproductie af als het melkveebedrijf groot is in termen van grondgebruik. Dit suggereert dat, als gevolg van de melkprijsdaling, het aantal bedrijven dat melk produceert afneemt en dat het vooral de kleine bedrijven zijn die hun melkproductie beëindigen. Dit biedt de overblijvende bedrijven de kans te groeien en de betere verdienmogelijkheden van grotere bedrijven uit te buiten. Het effect van de 2003 hervorming van het GLB op het inkomen van de overblijvende melkveebedrijven is daarom waarschijnlijk minder negatief dan berekend in een situatie zonder structurele veranderingen.

De micro-economische panel data modellen voor Nederlandse melkveebedrijven, ontwikkeld en geschat in dit proefschrift, vormen een flexibel instrument om de verwachte reacties op de 2003 hervorming van het GLB van Nederlandse melkveebedrijven te begrijpen. Ze zouden de bouwstenen kunnen zijn voor een volledig gespecificeerd huishoudproductiemodel voor Nederlandse melkveebedrijven. Met dit model zouden bijvoorbeeld de gevolgen van het introduceren van een vaste inkomenstoeslag per hectare gesimuleerd kunnen worden.

Training and supervision plan

Description	*Credits*[1]
Mansholt PhD courses:	
Mansholt Introductory Course	1
Mansholt Multidisciplinary Seminar	1
Discipline specific PhD courses:	
Macro Economics	4
Micro Economics	4
Econometrics	4
Advanced Econometrics	4
Economics of Household Behaviour (NAKE[2])	2
Topics in Applied Microeconomics (NAKE)	2
Maximum Entropy Econometrics: Theory and Practice	2
Baysian Analysis of Dynamic Economic Models using Simulation Techniques (NAKE)	2
Generalised Method of Moments: Theory and Practice	2
Behavioural Economics	2
Econometrics of Panel Data (NAKE)	2
NAKE workshops	6
Wageningen, December 2001:	
Russel Cooper on “Dynamic Programming”	
Christian Gollier on “The Economics of Risk and Time”	
Susanne Lohmann on “Why Some Groups Work and Others Don’t”	
Paul Ruud on “Limited Dependent Variable Models: Estimation with Simulation”	
The Hague, June 2002:	
Truman Bewley on “Wage Rigidity and Price Setting”	
Avinash Dixit on “Alternative Modes of Governance of Economic Transactions”	
Jerry Hausman on “Econometrics”	
Geoffrey M. Hodgson on “Recent Developments in Institutional Economics”	
Tilburg, December 2002:	
Patrick Bolton on “Incomplete Contracts and the Theory of the Firm”	
Lucrezia Reichlin on “Factor Models in Large Panels of Time Series”	
Kerry Smith on “Choice and Economic Value”	
Rotterdam June 2003:	
Manual Arellano on “Panel Data Econometrics”	
Gilles Saint-Paul on “The Future of Labor”	
Mark P. Taylor on “The Economics of Exchange Rates”	
General PhD courses:	
Scientific Writing	1
Career Perspectives	1

Teaching activities:	**2**
Practical sessions for Econometrics	
Practical sessions for Advanced Econometrics	
Practical sessions for Generalised Method of Moments: Theory and Practice	
Oral presentations:	**2**
10th EAAE Congress, 28-31 August 2002, Zaragoza, Spain	
1st European/EAAE PhD Workshop, 19-20 June 2003, Montpellier, France	
25th IAAE Congress, 16-22 July 2003, Durban, South-Africa	
NAKE DAY, 24 October 2003, Amsterdam, The Netherlands	
89th European Seminar of the EAAE, 2-5 Februari 2005, Parma, Italy	
AAEA 2005 Annual Meeting, 24-27 July 2005, Providence, RI USA	
11th EAAE Congress, 23-27 August, Copenhagen, Denmark	
2nd European/EAAE PhD Workshop, 22-23 September 2005, Wageningen, The Netherlands	
NAKE DAY, 21 October 2005, Amsterdam, The Netherlands	
Total (min 20 credits)	**44**

[1] 1 credit point represents 40 hours; [2] NAKE stands for Netherlands Network of Economics

Curriculum vitae

Daan L. Ooms is geboren op 7 januari 1977 te Hardenberg en getogen in Bruchterveld. In 1995 heeft hij zijn VWO diploma gehaald aan het Vechtdal College in Hardenberg. Daarna is hij begonnen aan een studie econometrie aan de Erasmus Universiteit Rotterdam waar hij in 2001 is afgestudeerd in de richting algemene econometrie.

In 2001 begon hij als onderzoeker in opleiding aan een promotieonderzoek bij de vakgroep Agrarische Economie en Plattelandsbeleid van Wageningen Universiteit. Hij heeft practicumcolleges begeleid voor verschillende econometrievakken voor bachelor- en masterstudenten en promovendi. In 2004 heeft hij gedurende drie maanden een deel van zijn onderzoek uitgevoerd aan de North Carolina State University in Raleigh, North Carolina in de Verenigde Staten. In 2005 haalde hij het diploma van het landelijke Netwerk Algemene en Kwantitatieve Economie (NAKE).

Sinds oktober 2006 werkt hij voor TNO arbeid in Hoofddorp. Hier is hij onderzoeker adviseur en houdt zich voornamelijk bezig met econometrische modellen die worden gebruikt om de effectiviteit te bepalen van interventies ter bevordering van arbeidsparticipatie. Twee voorbeelden hiervan zijn interventies om de ziekteverzuimduur van werknemers te bekorten voor een grote Nederlandse verzekeringsmaatschappij en interventies om mensen uit de bijstand te krijgen in de gemeente Rotterdam.

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