Micro econometric models for agricultural sector analysis

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Abstract

Micro econometric models are a useful tool for agricultural sector analysis. This paper provides a discussion of methodological aspects in the construction of micro econometric models. Attention is paid to the theoretical background, data requirements, empirical model selection and the estimation procedure. A discussion of several applications demonstrates the usefulness of micro econometric models for agricultural sector analysis.

Keywords: Panel data, Household Production models, Risk Models, Dynamic Models

1 Introduction

In the past decades, environmental and agricultural policies have become increasingly farm specific. Examples of farm-specific policy measures are the 1992 CAP reform, where the compensatory payments for farmers depend on farm-specific factors as region and size of the farm. Also, tradable quotas on milk (in EU countries) and emissions (phosphates in the Netherlands) are examples of farm-specific policy measures, in particular because the initial quota is based on historical production and use levels ('grandfathering'). Analysis of farm-specific policy measures needs to be done using models that determine the effects of behaviour for groups of farms or individual farms. Models of individual farms are also required for the analysis of many other decision problems that depend on farm-specific factors such as investments in new farm assets (which depend on liability) and off-farm work decisions (which depend on the availability of household labour).

Micro econometric models are a useful tool in the analysis of farm-specific behaviour since they explicitly model the behaviour of individual farmers. Micro econometric models are defined as a set of behavioural relationships that are based on micro economic theory and estimated on farm data using econometric techniques. In the economics literature, micro econometric models have been developed for explaining input demand and output supply behaviour (profit functions) in combination with explaining household decisions (household models), income risk (risk models) and investments in fixed assets (investment models). The purpose of this paper is to discuss the methodological aspects of constructing micro econometric models and to provide an overview of several applications.

The remainder of this paper is organised as follows. Section 2 discusses the theoretical background of four groups of micro econometric models: profit function models, household production models, risk models and investment models. Data requirements are discussed in section 3. Next, attention is paid to criteria for selecting functional forms (section 4) and to issues in the estimation of the functions that reflect the behavioural relationships (section 5). The paper ends with a discussion of several applications that demonstrate the usefulness and limitations of micro econometric models.

2 Theoretical framework

In this section the theoretical framework of profit function models, household production models, risk models and investment models is discussed.

2.1 Profit function models

Neo-classical production theory forms the framework for profit function models. The theory is more widely discussed in Chambers (1988) and is only briefly be surveyed here. Profit function models are useful in analysing the effects of price changes (e.g. through taxation) and changes in fixed factors (e.g. changes in the amount of land and supply quotas). Farm-specific effects of e.g. policy changes can be aggregated to sector level.

The theory behind profit function models assumes that farmers maximise profit conditional on a convex production possibility set or technology T. This can be denoted as:

$$\pi(\mathbf{p},\mathbf{w},\mathbf{z}) = \max_{\mathbf{y},\mathbf{x}} \{ \mathbf{p}'\mathbf{y} - \mathbf{w}'\mathbf{x} \mid (\mathbf{y},\mathbf{x},\mathbf{z}) \epsilon T \} \qquad (1)$$

where, **y** and **x** are vectors of quantities of outputs and variables inputs and **p** and **w** are the corresponding vectors of prices; **z** denotes the quantity of factors that are assumed to be fixed in the short term (e.g. supply quotas, labour, land, capital).

So the profit function gives the maximum profit a farm can reach given the input and output prices it is confronted with and the quantity of the fixed factors available on the farm. Given that supply quotas and other factors are taken fixed implies that a short term profit function is used. If factor use is (partly) endogenised a medium or long term profit function can be derived. Prices instead of quantities of the factors would then enter the profit function.

Differentiating the profit function with respect to price of output j and input i respectively (applying Hotelling's Lemma) yields the supply function of output j:

$$\frac{\partial \pi(\mathbf{p},\mathbf{w},\mathbf{z})}{\partial p_j} = y_j(\mathbf{p},\mathbf{w},\mathbf{z}) \qquad j = 1,\dots,M \qquad (2)$$

and the demand function for input i:

$$\frac{\partial \pi(\mathbf{p},\mathbf{w},\mathbf{z})}{\partial w_i} = -x_i(\mathbf{p},\mathbf{w},\mathbf{z}) \qquad i = 1,\dots,N \qquad (3)$$

The supply and demand function show the relation between output supply and input demand and the output prices, input prices and the quantities of fixed factors. Technological change is in these models usually modelled as a fixed factor.

Differentiating the profit function with respect to fixed factor k yields the shadow price q of this fixed factor:

$$\frac{\partial \pi(\mathbf{p},\mathbf{w},\mathbf{z})}{\partial z_k} = q_k(\mathbf{p},\mathbf{w},\mathbf{z}) \qquad k = 1,\dots,K \qquad (4)$$

The shadow price of a fixed factor shows the money the farm is willing to pay for an extra unit of this fixed factor. It is also possible to assume a fixed output (e.g. production under a quota). The shadow price of a fixed output shows the extra (marginal) costs of producing one extra unit. In case of a supply quota the difference between the market price of the output and the shadow price of production gives the maximum amount of money the farmer would be willing to pay for an extra quota right (the shadow price of the quota right).

2.2 Household production models

Household production models are a useful tool if issues related to agricultural households are of interest, i.e. off-farm and on-farm employment and savings. In household production models farms are divided into a production unit and a household (see Thijssen, 1988 and Elhorst, 1994). The relation between both is that the household supplies factors (labour and capital) to the production unit (and in household production models for developing countries the production unit supplies output to the farm household). It is assumed that the production unit maximises profit, and therefore, the profit function model as discussed in the previous section applies. In addition, there are demand functions for factors originating from the household. For the household utility maximisation is assumed. From utility maximisation the supply of factors and consumption follows. Factors can be used either in the production unit or supplied outside the farm (off-farm employment).

A general algebraic formulation of the household side of a household production model will be described below (see Varian, 1992:144-146). The indirect utility function gives the utility of the household as a function of prices of commodities and factors and income. The indirect utility function is given by:

$$v(\mathbf{w}'\mathbf{q}+E,\mathbf{w}) = \max_{x}\{U(\mathbf{x}) : \mathbf{w}'\mathbf{x} = \mathbf{w}'\mathbf{q}+E\} \qquad (5)$$

where: $v(\cdot)$ is the indirect utility function, $U(\mathbf{x})$ the direct utility function, $\mathbf{w}$ the vector of commodity and factor prices, $\mathbf{q}$ the vector of endowments of commodities and factors, E exogenous income and $\mathbf{x}$ the vector of demanded commodities and factors.

Given the indirect utility function, by using Roy's identity, it is possible to derive the Marshallian or uncompensated demand functions for commodities and factors. Roy's identity is given by:

$$\frac{\dfrac{\partial v(Y,\mathbf{w})}{\partial w_i}}{\dfrac{\partial v(Y,\mathbf{w})}{\partial Y}} = -x_i(Y,\mathbf{w}) \qquad i = 1,\ldots,N \qquad (6)$$

with:

$$Y = \mathbf{w}'\mathbf{q} + E \qquad (7)$$

The net demand for factor i ($x_i^n(Y,\mathbf{w})$) is given by:

$$x_i^n(Y,\mathbf{w}) = x_i(Y,\mathbf{w}) - q_i \qquad i = 1,\ldots,N \qquad (8)$$

where i denotes the i-th factor or commodity. The net demand for a factor or a commodity may be negative (e.g. for labour and capital) in which case the household is a net supplier of these factors.

2.3 Risk models

In the literature, uncertainty is included either directly through the specification of an Expected Utility or Mean-Variance function (Collender and Zilberman, 1985; Babcock et al.,1987), or indirectly through the incorporation of wealth variables (Chavas and Holt, 1990). Coyle (1992) and Oude Lansink (1999) have employed a Linear Mean-Variance approach in a micro economic framework that accounts for the role of price risk in producer behaviour[1]. Their approach allows for simultaneously determining the producers risk attitude and input demand and output supply behaviour.

In the linear mean-variance (LMV) framework, the preference ordering of an agents alternatives and expected utility are determined by the mean (M) and variance (V) of random payoff or income

$$U = M - \frac{1}{2}\alpha V \tag{9}$$

where α is the coefficient of absolute risk aversion, i.e. $\alpha > 0$, $=0$ and < 0 indicate risk aversion, risk neutrality and risk affinity respectively. Mean income is defined as :

$$M = \mathbf{p}'\mathbf{y} - C(\mathbf{w},\mathbf{y},\mathbf{z}) \tag{10}$$

where **p** is the mean output price vector; **w** is an input price vector; **y** and **z** are vectors of output quantities and quantities of fixed inputs; $C(\mathbf{w},\mathbf{y},\mathbf{z})$, defined as $\mathbf{w}'\mathbf{x}$, is a cost function with regular properties (Chambers, 1988:52). Assuming output prices are the only source of uncertainty that the producer is facing, the variance of random income is given by :

$$V = \mathbf{y}'\mathbf{Vp}\,\mathbf{y} \tag{11}$$

where **Vp** is the (symmetric, positive definite) covariance matrix of output. The indirect utility function corresponding to (11) is:

$$v^{*}(\mathbf{p},\mathbf{w},\mathbf{Vp},\mathbf{z}) = \max_{\mathbf{y}}\left(\mathbf{p}'\mathbf{y} - C(\mathbf{w},\mathbf{y},\mathbf{z}) - \frac{1}{2}\alpha\,\mathbf{y}'\mathbf{Vp}\,\mathbf{y}\right) \tag{12}$$

with first order condition :

$$\mathbf{p} - C_{y}(\mathbf{w},\mathbf{y},\mathbf{z}) = \alpha\,\mathbf{Vp}\,\mathbf{y} \tag{13}$$

The familiar "price is marginal cost" condition is obtained if either α is zero or if price variance is zero (i.e. **Vp** is a null matrix). $\alpha > 0$ implies that the output price exceeds marginal costs, implying that output is lower than optimal output under risk neutrality. As under risk neutrality or price certainty, first order condition (13) characterises output supply, i.e. by solving for y to yield $\mathbf{y}^{*}$ as a function of **w**, **z** and moments of the random output price:

$$\mathbf{y}^{*} = \mathbf{y}(\mathbf{p},\mathbf{w},\mathbf{Vp},\mathbf{z}) \tag{14}$$

Furthermore, by using the envelope theorem and first order condition (13) it can be shown that variable input demand equations can be obtained by differentiating either $v^{*}(\mathbf{p},\mathbf{w},\mathbf{Vp},\mathbf{z})$ or $C(\mathbf{w},\mathbf{y},\mathbf{z})$ with respect to input prices **w**.

$$x(\mathbf{p},\mathbf{w},\mathbf{Vp},\mathbf{z}) = -\frac{\partial v^{*}(\mathbf{p},\mathbf{w},\mathbf{Vp},\mathbf{z})}{\partial \mathbf{w}} = \frac{\partial C(\mathbf{w},\mathbf{y}^{*},\mathbf{z})}{\partial \mathbf{w}} = x(\mathbf{w},\mathbf{y}^{*},\mathbf{z}) \tag{15}$$

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[1] Coyle (1999) has extended this approach to account for both price and yield uncertainty.

2.4 Investment Models

In the Neo-classical literature on investments both primal and dual approaches for explaining investments within the adjustment cost framework have evolved. The primal approach requires an explicit specification of the adjustment cost function and uses a closed form solution for the Euler equation to derive a factor demand equation. Whereas a solution is tractable for a standard quadratic adjustment cost function, the problem becomes highly complex for more flexible specifications of adjustment costs, e.g. interactions between investments and the capital stock or third order effects (Pindyck and Rotemberg, 1983; Shapiro, 1986). More recently, GMM estimation procedures are employed in order to estimate Euler equations directly, thereby allowing for the estimation of more complicated functional approximations of the adjustment cost function (Pfann and Palm, 1993; Hamermesh and Pfann, 1996; Whited, 1998).

The dual approach on the other hand allows for deriving factor demand equations directly from an optimal value function (McLaren and Cooper, 1980; Epstein, 1981). Estimates of the dual function reveal some of the characteristics of the underlying adjustment cost function.

The standard dual model starts with the maximisation of the discounted flow of profit for the firm producing multiple outputs using variable and multiple quasi-fixed factors taking the form

$$J(\mathbf{v}, \mathbf{w}, \mathbf{k}, \mathbf{z}, \mathbf{t}) = \max_{\mathbf{I}} \int_{t}^{\infty} e^{-rs} [\pi(\mathbf{v}, \mathbf{k}(s), \mathbf{z}(s), s) - \mathbf{w}'\mathbf{k} - C(\mathbf{I}(s))] ds \tag{16}$$

where **k** is a vector of quasi-fixed inputs and **I** is the corresponding gross investments; π is defined as **v'y**; **v** and **w** are (vectors of) market prices of netputs and quasi-fixed inputs, respectively; **y** is a vector of netput quantities (positive for outputs, negative for inputs) and **z** a vector of fixed inputs; s reflects technological progress as a time trend; and C(I) is the adjustment cost function which is assumed to be continuous and differentiable, convex and symmetric around I=0.

The Hamilton-Jacobi equation of the optimization problem in (16) has the form

$$rJ(\mathbf{v}, \mathbf{w}, \mathbf{k}, \mathbf{z}, \mathbf{t}) = \max_{I} \{\pi(\mathbf{v}, \mathbf{k}, \mathbf{z}, \mathbf{t}) - \mathbf{w}'\mathbf{k} - C(\mathbf{I}) + (\mathbf{I} - \mathbf{k})' J_k\} + J_t. \tag{17}$$

Assuming an interior solution, the first order condition of this optimisation is $C_I = J_k$, implying that the shadow value of capital equals the marginal adjustment cost. Netput equations are derived by differentiating the optimised Hamilton-Jacobi equation in (17) with respect to **v** and applying the envelope theorem to yield

$$\mathbf{y} = rJ_v - J_{kv} \dot{\mathbf{k}} - J_{tv}. \tag{18}$$

Differentiating the optimal value function with respect to quasi-fixed factor prices and applying the envelope theorem gives investment demand equations:

$$\dot{\mathbf{k}} = J_{kw}^{-1} (rJ_w + \mathbf{k} - J_{tw}). \tag{19}$$

3 Data

Constructing micro econometric models requires the estimation of behavioural relationships on farm level data. Panel data are data from a set of individuals (e.g. farms) over a number of years. These data are now becoming more frequently available for economic research (e.g. FADN data are available in most EU countries).

Panel data can be balanced or unbalanced, where a panel data set is balanced if all farms are in the sample during the whole time period the data set covers and unbalanced if farms rotate in and out the sample, with unbalanced panel data being more frequently available.

Usually, the 'raw' panel data need some transformation before they can be used in the estimation of behavioural relationships and the researcher needs to make a number of decisions. First, the researcher needs to construct a number of input and output categories from the large number of inputs and outputs that are available in the data set. Aggregating inputs and outputs implies that weak separability assumptions are made. A set of inputs H is weakly separable from another set of inputs J if the marginal rate of input substitution of H is independent of J (Chambers, 1988). The number of inputs and outputs should be large enough to reflect the technological conditions of the production process on the one hand. On the other hand, a too large number of inputs and outputs results in functions that are more difficult to estimate, and increases the probability of the occurrence of 'zero' observations. Also, the objective of the research may determine the number and composition of inputs and outputs, i.e. a model designed to determine the effects of a tax on N-fertiliser should include N-fertiliser as a separate input.

Second, in static models (profit function models, household models and risk models) the researcher needs to make a distinction between short term fixed and short term variable inputs and outputs. Generally, inputs and outputs are treated as fixed factors if their quantities cannot be adjusted in the short term without making significant adjustment costs. Usually, land, (family) labour and capital invested in buildings and machinery are examples of inputs that are considered fixed in the short term. Output or emission quota are often assumed to be fixed if quota trade is not allowed for or if quota trade is subject to severe restrictions (e.g. if quotas are tied to land. In investment models, demand and supply equations are derived for short term fixed inputs and outputs, where short term fixed inputs and outputs differ from short term variable inputs and outputs by their rate of adjustment.

A third consideration in the preparation of data is the choice of the units of the variables in the equations. Aggregating several small inputs or output in aggregate input or output indexes requires the use of monetary units. Also, capital is measured in units and it is important to keep in mind that the monetary units of the LHS and RHS variables are referring to the same base year. This can be achieved by calculating implicit quantity indexes as the ratio of value to the own price index, where all price indexes have the same base year.

The fourth consideration in the construction of the data involves the calculation of price indexes of the aggregate input and output quantities. A suitable price index is the Tornqvist price index which takes the following form for an input or output composed of k components on farm h:

$$Log\,P_{th} = \sum_{i=1}^{k} 0.5(s_{ith} + s_{ib}) \cdot (\log p_{ith} - \log p_{ib}) \qquad (20)$$

where: P_{th} Tornqvist price index for the input or output in year t on farm h, s_{ith} share of component i on farm h in year t, s_{ib} average share of component i in base year, p_{ith} price index of component i for farm h in year t and p_{ib} average price of component i in base year.

The price index given in (20) is not the price index that is used. The price index that is finally used is obtained by averaging (20) over all farms in the sample in one year. Therefore, the Tornqvist price indexes vary over the years but not over the farms, implying that differences in the composition of an aggregate input or output or differences in the quality, are reflected in the quantity (Cox and Wohlgenant, 1986).

4 Choice of functional form

This section discusses criteria and considerations that underly the choice of the functional form that reflect the behavioural relationships of the farms in the micro econometric model. Selection of functional forms has been the subject of numerous studies in the economics literature. One branch of this literature has based the selection of functional forms on Monte Carlo studies which examine the ability of various forms to track a known technology (Guilkey et al., 1983). A second branch uses real data and estimates the Generalised Box-Cox (Box and Cox, 1963), which is considered to be the true function underlying the data generating process. The Generalised Box-Cox includes a variety of functions as nested hypotheses and parametric tests are carried out to test against the Generalised Box-Cox (Applebaum, 1978; Chalfant, 1984; Oude Lansink and Thijssen, 1998). A third approach to selecting functional forms uses ad hoc selection criteria such as theoretical consistency, domain of applicability, flexibility, computational ease, satisfying theoretical conditions and plausibility of the results (Lau, 1986; Baffes and Vassavada, 1989).

Selecting among functional forms for micro econometric models may involve all three methods described above. However, some restrictions need to be taken into account, that limit the choice possibilities. First, a micro econometric model that is based on neo-classical production theory should satisfy theoretical conditions as linear homogeneity, monotonicity and curvature conditions (convexity or concavity in prices). A literature review by Shumway (1995) shows that, if not imposed, the condition of convexity in prices is often violated in profit function models. The problem that curvature conditions are not satisfied is found for other approaches as well. Therefore, the functional form that is selected should allow in particular for imposing curvature conditions. Second, it should be noted that micro econometric models require the estimation of behavioural relationships on farm level data that often include negative profits (e.g. Helming et al., 1993; Moschini, 1988) and zero values for inputs and output.

The use of the popular flexible forms, Generalised Leontief and the Translog is ruled out *a priori*, since curvature conditions cannot be imposed on these functional forms without destroying their flexibility (Diewert and Wales, 1987). Moreover, the square root and logarithmic transformations cannot be applied to negative and zero values. Two functional forms that are capable of satisfying these conditions are the Normalised Quadratic (Lau, 1978) and the Symmetric Normalised Quadratic (Diewert and Wales, 1987; Kohli, 1993). The Normalised quadratic has the following general structure for a profit function[2]:

$$\pi^* = \alpha_0 + \alpha_v{}'\mathbf{v}^* + \alpha_z{}'\mathbf{z} + 0.5\ \mathbf{v}^{*\prime}\alpha_{vv}\mathbf{v}^* + 0.5\ \mathbf{z}'\alpha_{zz}\mathbf{z} + \mathbf{v}^{*\prime}\alpha_{vz}\mathbf{z} \qquad (21)$$

Where $\mathbf{v}^*$ are normalised netput prices and **z** are fixed inputs and outputs. The normalised quadratic is a relatively simple functional form, but has the important drawback that its estimation results depend on choice of the *numeraire* input or output, i.e. the input or output price that is used to impose linear homogeneity of the profit function in prices.

The Symmetric Normalised Quadratic has the general structure for a profit function:

$$\pi = \alpha_v{}'\mathbf{v} + 0.5(\theta'\mathbf{v})^{-1}\mathbf{v}'\alpha_{vv}\mathbf{v} + 0.5(\theta'\mathbf{v})\,\mathbf{z}'\alpha_{zz}\mathbf{z} + \mathbf{v}'\alpha_{vz}\mathbf{z} \qquad (23)$$

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[2] It has a similar structure for a cost function or an optimal value function.

where, v represent nominal netput prices. Linear homogeneity of the profit function in prices is imposed by the fixed weight price index θv. Note that all prices are used to impose linear homogeneity in prices and that the Symmetric Normalised Quadratic gives estimation results that are invariant to the choice of the numeraire.

5 Estimation Issues

Estimation of a micro econometric model using panel data of farms should account for heterogeneity among farms in a sample. Accounting for heterogeneity is achieved by employing panel data estimation methods that typically allow for the estimation of farm-specific parameters. Two classes of panel data estimation methods are considered in this paper, i.e. a class of 'traditional' least squares or maximum likelihood methods and a relatively new class of Generalised Maximum Entropy methods.

Among the class of least squares or maximum likelihood methods, the Fixed Effects approach is the most prominent in the estimation of systems of input demand and output supply equations in the agricultural economics literature (see Baltagi, 1995, for an overview). The advantages of this method are its computational ease and the fact that it gives consistent estimates, when the explanatory variables correlate with the farm specific intercept. The Random Effects approach is another estimation method in the class of least squares or maximum likelihood methods. The Random Effects approach gives more efficient estimates than the Fixed Effects approach. However, the Random Effects estimates are only consistent if the explanatory variables are orthogonal to the firm specific effect. The orthogonality assumption in the Random Effects model can be tested using a Hausman test (Hausman, 1978) and is often rejected in the agricultural economics literature (Thijssen, 1992; Gardebroek and Oude Lansink, 1999). Hausman and Taylor (1981) proposed an alternative estimator to the Fixed and Random effects models. The Hausman-Taylor model discriminates between explanatory variables that correlate with the farm-specific effects and explanatory variables that are independent of the farm-specific effect. The Hausman-Taylor model gives consistent estimates, but is more efficient than the Fixed effects model. Gardebroek and Oude Lansink (1999) provide a Hausman-Taylor estimator for estimating systems of equations on unbalanced panel data.

A general characteristic of the least squares and maximum likelihood methods for estimating systems of equations in micro econometric models is that farms are assumed to have equal slope parameters and the farm-specific effect enters the equations as intercepts (Fixed Effects) or draws from a distribution (Random Effects, Hausman-Taylor model). This assumption is restrictive, since there is no reason to assume *a priori* that heterogeneity only enters the equations to be estimated as slope shifters. However, increasing the number of farm-specific parameters may be computationally cumbersome and results in a rapid decrease of the number of degrees of freedom and estimation precision.

An alternative for the class of traditional methods is a class of methods entitled Generalised Maximum Entropy estimation (see Golan et al., 1996). The advantage of this method is that it can estimate a system of equations that is fully farm-specific, i.e. through intercepts and slope parameters. The GME method has recently been applied to the estimation of farm-specific systems of input demand and output supply equations by Oude Lansink (1999) and to the estimation of farm-specific cost functions by Paris and Howitt (1998).

6 Overview of applications

This section provides a discussion of several applications that demonstrate the usefulness and limitations of micro econometric models. The overview of applications in this paper is limited to agricultural economic applications.

6.1 Profit function models

Following the first applications of duality theory in the agricultural economics literature in the early seventies (e.g. Lau and Yotopoulos, 1972), profit functions have by now been widely adopted by agricultural economists in the analysis of economic problems. A comprehensive overview of applications of profit and cost function models can be found in Shumway (1995). Profit function models have proven their usefulness in the analysis of a wide range of policy measures, such as set-aside policies (Oude Lansink and Peerlings, 1996), systems of mineral surplus taxes (Oude Lansink and Peerlings, 1997; Fontein et al., 1994) and systems of quota. Moschini (1988) and Helming et al. (1993) analysed the effects of the dairy quota systems in Canada and the Netherlands, respectively. Burton (1989) and Guyomard et al. (1996) analysed the effects of unrestricted dairy quota trade, whereas Oude Lansink and Peerlings (1995) analyse the effects of tradable and non-tradable N-fertiliser quota. Weninger (1998) assesses the effects of individual transferable fish quota. Babcock and Foster (1992) focus on the distribution of quota rents between owners and renters of marketable production quotas for tobacco in the US. Extensions to the basic model of quota trade are made Guyomard et al. (1995) with a siphon on dairy quota trade and by Boots et al. (1997) with the incorporation of upper and lower bounds on quota transactions. Bureau, et al., (1997) model quota mobility in the European sugar regime where they distinguish between A, B and C sugar, whereas Boots and Peerlings (1999) use a similar model to model the effects of a two-tier price system on dairy quota prices. Gardebroek et al. (1999) focus on the effects of technical factor utilisation on quota values.

6.2 Household production models

Applications of household production models are mainly in the area of household labour supply to the production unit of farms and in the area of off-farm employment (for an apllication for capital supply see Benjamin and Phimister, 1997). Traditionally economists assumed that production conditions affect consumption and labour supply to the production unit exclusively via income levels, and that production decisions are entirely independent of decisions about consumption and labour supply (see Singh, et al., 1986 for an overview of this empirical literature). Lopez (1984), Thijssen (1988) and Elhorst (1994) developed micro econometric models that integrate the production and labour decisions of a farm household into a unified theoretical framework. The budget constraint is linearised in order to exploit the body of established results of traditional demand theory.

Another body of literature investigates off-farm employment. Although well documented for North America (see Hallberg, 1991), literature on off-farm work is scarce for Europe. An exception is Woldehanna, et al. (2000) who analyse the effects of the CAP reform on off-farm employment using a double hurdle model. In double hurdle models first the decision to work outside the farm is taken and in a second step the size of off-farm employment is determined. Examples of non-EU off-farm employment analyses are Kimhi (1996a) who investigates the role of farm work status on off-farm employment decisions; Kimhi (1996b) who looks at the effects of unobserved group effects on the allocation of time between farm work and off-farm work; Mishra and Goodwin (1997) who look at the role of income variability on off-farm employment and Tavernier et al. (1997) who examine the role of farm ownership on off-farm labour supply of farmers.

6.3 Risk models

In recent years, several authors applied the Mean-Variance framework thereby accounting for the role of price risk. Coyle (1992) applies the M-V framework to provincial data on livestock and crops production in Manitoba. However, his approach does not allow for estimating the producers risk attitude (see Coyle, 1994). Saha (1996) adopts a mean standard deviation framework that is capable of estimating the production technology along with the producers risk attitude. His approach allows for identifying different risk configurations, i.e. of increasing, constant and decreasing absolute and relative risk aversion. Saha applies the mean standard deviation approach to panel data of Kansas wheat producers and finds that producers are characterised by decreasing absolute and constant relative risk aversion. Oude Lansink (1999) adopts a Mean-Variance framework that simultaneously determines the producers risk attitude along with the producers optimal input demand, output supply and allocation of areas to different crops. His application to panel data of specialised Dutch cash crop farms shows that producers are risk averse.

Coyle (1999) provides an extension to the literature mentioned above by developing a Mean-Variance approach that accounts for both yield and price uncertainty. This framework determines the producers risk attitude along with optimal input-output decisions and is applied to provincial data of livestock and crops production in Manitoba.

Despite their relevance in the analysis of agricultural policy measures in general, risk models have not been as widely adopted to date as profit function or household production models.

6.4 Investment models

Applications of the primal dynamic model in the agricultural economics literature are rare to date. Lopez (1985) modelled investments in the Canadian food processing industry using aggregate data and Thijssen (1994 and 1996) focused on investments on Dutch dairy farms using panel data.

The dual dynamic model has gained substantial popularity in the agricultural economics literature following its theoretical development by Epstein (1981) and McLaren and Cooper (1980). Vasavada and Chambers (1986), Leblanc and Hrubovcak (1986) and Vasavada and Ball (1988) applied the dual dynamic model to annual data on U.S. agricultural production. Howard and Shumway (1988) used annual data on U.S. dairy production to investigate dynamic adjustments in the dairy industry. More recently, Luh and Stefanou (1991, 1993) extend measures of growth and learning to the dynamic case using annual data of U.S. agricultural production. Applications of the dual dynamic model using panel data include Fernandez et al. (1992) focusing on long term measures of economies of scope and scale and Stefanou et al. (1992) who focus on the production structure of the German dairy industry before and after the introduction of the milk quota. Chang and Stefanou (1988) and Oude Lansink and Stefanou (1997) analyse asymmetric adjustment costs using panel data of dairy and cash crop farms that display a typical pattern of disinvestments, zero investments and investments in farm assets.

A general conclusion with respect to investment models is that they have not been widely adopted in the analysis of (farm)-specific policy measures.

7 Conclusion

This paper has provided a discussion of methodological aspects in the construction of different micro econometric models, i.e. profit function models, household production models, risk models and investment models. Attention was paid to the theoretical background, data requirements, empirical model selection and the estimation procedure. The usefulness and limitations of different micro econometric models for policy analysis has been illustrated through a discussion of several applications. It is found that risk models and investment models have not been widely adopted in the analysis of (farm-specific) policy measures and that they need further development for these purposes. Future research should also increasingly attempt to account for farm heterogeneity, e.g. through the use of Generalised Maximum Entropy estimation methods. Finally, future research in micro econometric modelling should allow for a greater level of detail, both in terms of variables accounted for and in terms of (spatial) variation within farms in order to address environmental policy issues.

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