Uncertain Land Availability and Perceived Biases in Investment Decisions: The Case of Dutch Dairy Farms

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Abstract

Uncertainty about the possibility of acquiring land can be rather large in the EU for sectors like dairy farming. Farm-level investment decisions are commonly made *ex-ante* when the farmer is not certain about the possibility of purchasing land. This possibility is realized only in a future period. In this paper, we have developed and applied a simple two-period model in which a profit-maximizing farmer, facing uncertainty about the possibility of acquiring land, had to choose the optimal mix of capital (buildings) investment and land endowment. We have shown that commonly "observed" biases towards non-optimal investment decisions are not necessarily justified. Rather, these perceived biases may be the result of evaluating investment decisions without reference to the uncertainty associated with the possibility of acquiring land.

Keywords: investment, land, uncertainty

1. Introduction

Empirical observations suggest that capital rewards in agriculture are often non-optimal (Gardner, 1992). The fixed asset theory (Johnson and Passour, 1981) explains this by stating that farmers invest when the shadow price of capital exceeds the buying price of capital (acquisition costs) and disinvest when the shadow price of capital is lower than the selling price (salvage value). Because the selling price is lower than the buying price farmers accept factor rewards for capital between the buying and selling prices. Related to this theory is the observation that investments are irreversible, so capital involves sunk costs (e.g. Abel and Eberly, 1994, 1997). This leaves the question why farmers invest in the first place. Do they not foresee that the reward for capital sooner or later will be lower than the buying price? Should they not decide not to invest or to invest less? To explain investment decisions, the literature focuses on the shadow price of capital, adjustment costs and uncertainty in a dynamic setting (Abel and Eberly, 1997; Dixit and Pindyck, 1994). Adjustment cost theory states that capital adjustment to changing market conditions is not instantaneous, may take a long time and involves significant adjustments costs (e.g., Lopez, 1985). More specifically, changes in capital stock are associated with increasing delivery cost of machinery, increasing administrative costs required to handle the new investment, engineering costs related to the planning of capital expansion, and more. However, adjustment cost theory is not very helpful in explaining low capital rewards. Adjustment costs increase the costs of investing and therefore lead to smaller investments and capital stock.

The literature on uncertainty concentrates on uncertainty about prices, policies and technology movements (Dixit and Pindyck, 1994; Grenadier, 1997). These uncertainties lead to smaller investments, and therefore capital stock, if the expectation is that changes in price, policy and technology have a negative effect on profitability. Larger investments could come from expected improvements in profitability. For example, Alvarez et al (1998) show that the expectation of a future tax cut increases investment while a tax increase leads to smaller investments.

Uncertainties on policies and prices in the European Union (EU) are relatively low for sectors like dairy farming, given the EU-price support policy. However, uncertainty about the possibility of purchasing land can be rather large. Buying or renting land is often not possible for a specific farmer because she requires land close to her farm and the only possibility to buy or rent land is when her neighbor quits farming. Whether and when the neighbor will quit is unknown to her, but she has a priori expectations about the likelihood of these events. Uncertainty about the possibility of buying land is therefore in some cases (land intensive sectors) greater and more relevant than the uncertainty with respect to prices, policies and technology.

Another theory on investment where uncertainty plays an important role is options theory (Dixit, 1992 and Dixit and Pindyck, 1994). This theory suggests that if we know that the information in the next period will be better than in the current one, it could be worthwhile to postpone the investment. Notice that waiting leads to under-investment and higher factor rewards for capital in the current period. The lower profit in the current period could be compensated by the extra profit obtained in the next period due to better information. Crucial here are the assumptions that the information in the next period is better than the information today, that investment can be postponed and that investment involves sunk costs. The first two assumptions are often rather unrealistic. For example in the EU it is not clear if and when the dairy policy will be reformed and there is no reason to believe that next year the information will be better. Postponing investment is also not always possible, for example, because there is a limit to the time period a building license can be used, or the state of buildings requires immediate investing.

The purpose of this paper is to examine the influence of uncertainty about the possibility of buying land on investment decisions. Moreover, we examine if uncertainty about the possibility of buying land can explain the perceived low capital rewards. Towards this aim, we develop and apply a simple two-period discrete-time investment model. With the model we analyze the effect of expectations of farmers about the possibility of buying extra land in the future (period 2) on investment in the current period (period 1). Moreover, we determine whether the model leads to higher investment and lower capital rewards, compared to the case where this possibility is ignored. Essential in our model is the assumption that farmers make investment decisions in period 1 *ex-ante*, prior to observing the realization of the possibility of acquiring additional land in period 2. However, we also investigate whether, and under what conditions, investment for an individual farm in period 2 is preferred to investment in period 1 (options theory). The model is applied for individual Dutch dairy farmers.

This paper makes three contributions to the literature. First, it investigates the role of uncertainty about the possibility of buying land on investment decisions. Second, it examines whether the over-investment in agriculture often perceived can be explained by this uncertainty. Finally, it applies the developed model of investment to individual Dutch dairy farmers, and therefore takes into account the diversity among farmers.

Section 2 derives analytically the optimal investment levels in period 1 under uncertainty about the possibility of purchasing land in period 2. Then it examines whether or not investment is higher under uncertainty about the possibility of buying land than under certainty. Next, it investigates whether postponing investment until period 2 is profitable or not and under what conditions. Section 3 discusses the empirical model. Using a static profit function, the shadow price equations for land and buildings are derived which are used to derive the optimal investment levels under different assumptions about the probability of purchasing land and the period in which investment takes place (i.e., either period 1 or period 2). The data and estimation of the empirical model are also discussed in this section. Section 4 then discusses the simulations and results. Finally, section 5 concludes the paper.

2. Two-period investment model

This section presents a simple two-period investment model. Section 2.1 sets out some basic assumptions. Section 2.2 derives optimal investment under complete certainty about the possibility of purchasing land. Section 2.3 does this for the case of uncertainty. In section 2.4 it is shown whether and under what conditions there is a perceived bias towards either over-investment or under-investment. Finally, section 2.5 determines optimal investment if investment takes place in period 2 instead of period 1. Moreover, it determines whether it is optimal to invest in period 1 or 2.

2.1 Basic assumptions

Consider a risk-neutral profit-maximizing farmer facing investment decisions at the beginning of period 1 and an uncertain opportunity to purchase land from a neighboring farm(s) in the future. For simplicity, we assume a time horizon of only two periods: present (*ex ante*), *t=1* and future (*ex post*), *t=2*. The farm's product at period *1* is given by $f^1(K_0 + K, a)$, where $K_0 > 0$ is a predetermined level of initial capital stock, K represents the level of capital investment at the beginning of *t=1* and a is the land endowment available for cultivation during this period. Obviously, output is also dependent on variable inputs, which are not explicitly included in the production function. Focusing on the relationships between land and capital, we assume that the level of these inputs, in each of the two periods, is optimally chosen for any given combination of land and capital and a given set of parameter values. The production function is assumed to be monotonically increasing, twice differentiable and concave in both arguments: $f_x^1 = \frac{\partial f^1}{\partial x} > 0, f_{xx}^1 = \frac{\partial^2 f^1}{\partial x^2} < 0, x = K, a.$ Based on empirical evidence from Dutch dairy farms (see Section 3), we further assume that capital and land are complementary inputs, i.e., $f_{Ka}^1 = \frac{\partial^2 f^1}{\partial K \partial a} > 0.$

At the beginning of period 2*,* the farmer may have an opportunity to increase her land endowment if a neighbor will offer her farm-land for sale at the ongoing land market price of q dollars per hectare. If the farmer chooses to purchase land, b hectares will be traded, (assuming that $b \le \bar{b}$, where $\bar{b}$ is the total amount of land offered for sale by the neighbor). Capital adjustment to changing market conditions is not instantaneous, may take a long time and involves significant adjustment costs (e.g., Lopez, 1985). We assume that adjustment costs are only present in period 1, since investment in the basic capital stock, *K*, is made at the beginning of this period. To maintain this stock level in the second period, the farmer covers the depreciation costs associated with *K* at the beginning of period 2. No adjustment costs are involved in maintaining a given stock level or in changing the level of use of variable inputs.

Thus, the production level in period 2 is given by $f^2(K_0 + K, a + \theta b)$ where θ is an indicator function which is equal to 1 if the opportunity to purchase land at the beginning of t=2 exists and is equal to 0 otherwise. Like f^1, f^2 is assumed to be monotonically increasing, twice differentiable and concave in both arguments and, as in period 1, land and capital are assumed to be complements in period 2, i.e, $f_{Ka}^2 = \frac{\partial^2 f^2}{\partial K \partial a} > 0.$

2.2 Certainty versus uncertainty

Here we assume that in period 1 the farmer does not know with certainty whether she will be able to purchase land at the beginning of period *2*. Let $0 < \alpha < 1$ be the perceived probability that the land will be available for sale at the beginning of t=2, i.e., the probability that $\theta = 1$. Since K_0 is predetermined we will suppress it hereafter for notational convenience without loss of generality.

Recall that θ is known with certainty before the choice of b is made. Thus, if $\theta = 0$ than b=0 regardless the level of K which was determined *ex-ante*. If however, $\theta = 1$ the *ex-post* optimization problem is to choose b that maximizes $P^2 f^2(K, a+b) - qb$, where K is given and P^t is output price in the t^{th} period, $t = 1, 2$. The first order condition, $P^2 f_b^2(K, a+b)] - q = 0$, yields a derived demand for land, denoted here by $b = \hat{b}(K)$. It can be easily verified that $\frac{\partial \hat{b}(K)}{\partial K} = -\frac{f_{bK}^2}{f_{bb}^2} > 0.$

The farmer's *ex-ante* optimization problem is to choose K that will maximize expected profits. Formally,

$$
\begin{aligned}
(5) \max_{K \geq 0} E\Pi = {} & \alpha\{P^1 f^1(K,a) - (r+\omega)K + [P^2 f^2(K, a+\hat{b}(K)) - r(K+\beta K) - q\hat{b}(K)]\eta\} \\
& + (1\text{-}\alpha)\{P^1 f^1(K,a) - (r+\omega)K + [P^2 f^2(K,a) - r(K+\beta K)]\eta\} \\
& = P^1 f^1(K,a) - (r+\omega)K + [P^2 f^2(K,a) - r(K+\beta K)]\eta + \alpha\{P^2\eta[f^2(K, a+\hat{b}(K)) \\
& \text{-}\, f^2(K,a)] - q\hat{b}(K)\eta\}.
\end{aligned}
$$

where r is the acquisition price of capital, ω is the adjustment cost parameter, β is the rate of depreciation of capital and $0 < \eta < 1$ is the real discount rate. Focusing on the impacts of uncertainty about the possibility of purchasing land on investment decisions, we assume b to be strictly positive in the optimal solution. In other words, we focus our attention on farms for which the marginal value of the current land endowment (the shadow price of land), a, in the second period, exceeds (or does not fall short of) q.[1] For simplicity and without loss of generality we further assume that at the optimal solution $b < \bar{b}$. It should be also noted that the optimization problem in (1) assumes away the option of disinvestment (i.e., K<0). This assumption is based on

[1] Obviously, the option to sell land $(b < 0)$ is potentially available for the farmer under consideration, but from her own point of view it is not subject to uncertainty.

the fixed asset theory (e.g., Johnson and Pasour, 1981) which emphasizes the divergence between the acquisition values (see *Q* below) and the salvage prices of "identical" units of fixed assets, with the latter price being lower than the former value. In the analysis below we assume that the shadow price of capital always exceeds its market salvage price (implying $K \geq 0$).

The first order condition is

$$\frac{\partial \mathrm{E}\Pi}{\partial \mathrm{K}} = P^1 f_K^1(K,a) + P^2 \eta f_K^2(K,a) - Q + \alpha P^2 \eta [f_K^2(K,a+\hat{b}) - f_K^2(K,a)]$$
$$+ \alpha\eta [P^2 f_b^2(K,a+\hat{b}) - q] \frac{\partial \hat{b}(K)}{\partial K} \leq 0, \; (=0 \text{ if } K>0).$$

where $Q = \omega + r(1+\eta+\eta\beta)$.

Utilizing the first order condition for choosing $\hat{b}$, $P^2 f_b^2(K,a+\hat{b})] - q = 0$, we can rewrite the above condition as

(6) $$\frac{\partial \mathrm{E}\Pi}{\partial \mathrm{K}} = P^1 f_K^1(K,a) + P^2 \eta f_K^2(K,a) - Q$$
$$+ \alpha P^2 \eta [f_K^2(K,a+\hat{b}) - f_K^2(K,a)] \leq 0 \longrightarrow K = \hat{K}(\alpha).$$

Optimal expected profits are thus given by

(5a) $$\hat{\mathrm{E}\Pi}(\hat{K},\hat{b}) = P^1 f^1(\hat{K},a) - (r+\omega)\hat{K} + [P^2 f^2(\hat{K},a) - r(\hat{K} + \beta\hat{K})]\eta +$$
$$\alpha\{P^2\eta[f^2(\hat{K},a+\hat{b}(\hat{K})) - f^2(\hat{K},a)] - q\hat{b}(\hat{K})\eta\}.$$

Assuming an internal solution, a comparative statics with (6) yields,

(7) $$sign\left\{\frac{\partial \hat{\mathrm{K}}(\alpha)}{\partial \alpha}\right\} = sign\left\{P^2\eta[f_K^2(K,a+\hat{b}) - f_K^2(K,a)]\right\} > 0;$$

$$sign\left\{\frac{\partial \hat{\mathrm{K}}(\alpha)}{\partial Q}\right\} = sign\{-1\} < 0.$$

Finally, note that (5a) can be used to calculate the expected loss from imperfect ex-ante information on land availability at period 2 which is given by

(8) $$\mathrm{EL}(\alpha) = [\alpha\Pi^*(K^*,b^*) + (1-\alpha)\Pi^{**}(K^{**})] - \hat{\mathrm{E}\Pi}(\hat{K},\hat{b}).$$

Comparisons of capital investments under uncertainty and certainty conditions.

For $\alpha = 1$ there is complete certainty about the possibility to buy land for $\alpha = 0$ there is complete certainty that there is no possibility to buy land. Suppose optimal investment levels under both situations are K^* and with K^{**} respectively.

To compare $\hat{K}$ with K^* and with K^{**}, define

$$R^1(K) \equiv P^1 f_K^1(K,a) + P^2 \eta f_K^2(K,a) - Q, \;\; R^2(K,\hat{b}) = \alpha[P^2\eta(f_K^2(K,a+\hat{b}) - f_K^2(K,a))]$$

and note from (6) that $\frac{\partial E\Pi}{\partial K} = R^1(\hat{K}) + R^2(\hat{K},\hat{b}) \le 0.$

Since $R^2(K,\hat{b})$ is positive for any $\hat{b} > 0$ the first order condition in (6) can be satisfied only when $R^1(\hat{K})$ is negative. Noting that

$\frac{\partial R^1(K)}{\partial K} = P^1 f^1_{KK}(K,a) + P^2 \eta f^2_{KK}(K,a+\hat{b}) < 0$ we can conclude that if $K^{**} > 0,$ and therefore $R^1(K^{**}) = 0$, then $\hat{K}(\alpha) > K^{**}\ \forall 0 < \alpha \le 1.$ When K^{**} =0, $R^1(K=0)$ is negative and in that case $\hat{K}(\alpha)$ may be also equal to zero, at least for some values of α at its lower range. The above findings allow us to conclude that $\hat{K}(\alpha) \ge K^{**}\ \forall 0 < \alpha \le 1.$ To compare $\hat{K}(\alpha)$ with K^*, let us first assume that the latter is strictly positive and calculate the first order condition in (6) at $K = K^*$ (and $b = b^*(K^*)$). Noting with complete certainty to buy land that $P^1 f^1_K(K^*,a) - Q = -P^2 \eta f^2_K(K^*,a+b^*)$, we get

(6)' $$\frac{\partial \mathrm{E}\Pi}{\partial \mathrm{K}}(K = K^*) = (1\text{-}\alpha)P^2\eta[f^2_K(K^*,a) - f^2_K(K^*,a+b^*)] < 0,$$

implying $\hat{K}(\alpha) < K^*, \forall 0 \le \alpha < 1.$ It can be easily verified that $K^* = 0$ implies $\hat{K}(\alpha) = 0, \forall \alpha.$

The above analysis allow us to conclude

(9) $$0 \le K^{**} \le \hat{K} \le K^*.$$

If K^{**} is strictly positive, than the inequalities in (9) become strict inequalities.

The result identified in (9) suggests that observers who inspect farms for which the option to acquire additional land was not realized may conclude that actual investment is too high ($\hat{K} > K^{**}$). On the other hand, observation of investment decisions made by farmers who actually purchased land at the second period may yield the conclusion that actual investment is too low ($\hat{K} < K^*$). Both observations may be correct *ex-post*, but neither of them demonstrate that, *ex-ante*, farmers make non-optimal and biased investment decisions.

2.3 Perceived Biases Toward Non-Optimal Investment Decisions

By definition, $\hat{K}$ is the optimal *ex-ante* capital investment at t=1. Nevertheless, it may *appear* too high or too low if observers evaluate investment decisions without reference to their timing and informational structure. If a representative farmer had perfect information, the optimization process would result in an average level of investment, say $\bar{K}$, which is given by

(10) $$\bar{K}(\alpha) = \alpha K^* + (1-\alpha)K^{**}.$$

Observers unappreciative of the farmer's actual informational constraints may mistakenly identify a bias towards over-investment if $\hat{K} > \bar{K}$ and towards under-investment if the inequality sign is reversed.

To be more specific, assume first a farm for which $K^{**} > 0$, and therefore $K^{**} < \hat{K} < K^{*}$. To compare $\bar{K}$ with $\hat{K}$ note that both, $K^{*}$and K^{**} are independent of α and that $\frac{\partial \bar{K}}{\partial \alpha} = K^{*} - K^{**} > 0$.

Obviously, if $\alpha = 0$ then $\hat{K} = \bar{K} = K^{**}$and if $\alpha = 1$ than $\hat{K} = \bar{K} = K^{*}$. Recall from (7) that $\hat{K}$ is a monotone increasing function of α and note that

(11) $$sign\left\{\frac{\partial^2 \hat{K}}{\partial \alpha^2}\right\} = sign\left\{f_{KK}^2(K, a+\hat{b}) - f_{KK}^2(K, a)\right\}.$$

It is convenient now to utilize a graphical analysis. The function $\bar{K}(\alpha)$ is a monotone increasing and linear function (Figure1a). Inspection of (11) shows that the derivative $\frac{\partial \hat{K}}{\partial \alpha}$ is monotone increasing [monotone decreasing] in α if $f_{KK}^2(K, a+\hat{b}) > f_{KK}^2(K, a), [f_{KK}^2(K, a+\hat{b}) < f_{KK}^2(K, a)]$. This implies that if $\frac{\partial f_{KK}^2}{\partial b} > 0$, then the curve $\hat{K}(\alpha)$ is convex and, with the exception of its extreme point, lies below the curve $\bar{K}(\alpha)$, i.e., $\hat{K}(\alpha) < \bar{K}(\alpha), \forall \alpha \in (0,1)$, (see $\hat{K}^{II}(\alpha)$ in Figure 1a). Observers may (mistakenly) identify such a result as a bias towards under-investment. On the other hand, if $\frac{\partial f_{KK}^2}{\partial b} < 0$ then the curve $\hat{K}(\alpha)$ is concave and, with the exception of its extreme point, lies above the curve $\bar{K}(\alpha)$, i.e., $\hat{K}(\alpha) > \bar{K}(\alpha), \forall \alpha \in (0,1)$, (see $\hat{K}^{I}(\alpha)$ in Figure 1a). This result could certainly create a false impression of over-investment.

In the above analysis we assumed a farm for which $K^{**} > 0$. For a farm which chooses not to invest in capital at all, even under certainty with $\alpha = 1$, i.e., a farm for which $K^{*} = 0$, we get $\hat{K} = K^{**} = 0 \rightarrow \bar{K}(\alpha) = \hat{K}(\alpha) = 0, \forall \alpha$. Another potential situation is related to a farm for which $K^{*} > 0, K^{**} = 0$ and $\hat{K}(\alpha)\begin{cases} = 0 \text{ if } \alpha \le \underline{\alpha} \\ > 0 \text{ if } \alpha > \underline{\alpha}, \end{cases}$ where $\underline{\alpha}$ is some (endogenously determined) threshold level of α. For the sake of illustration, such a situation is depicted in Figure 1b with the curves labeled $\hat{K}^{I}(\alpha), \hat{K}^{II}(\alpha)$ and $\bar{K}(\alpha)$.

2.4 Option Value, the option to invest in period 2

Up to this point we have assumed that investment is made in period 1. In this section we examine the option to postpone investment to period 2. All decisions in period 2 are made *ex post*, after the value of θ is realized. The farmer's optimization problems for $\theta = 0$ and $\theta = 1$ are given respectively by

(12) $\max_{K\geq 0}\{\Pi = [P^2 f^2(K_0 + K, a) - (r+\omega)K - r\beta K_0]\eta\}$, and

(13) $\max_{K\geq 0, b}\{\Pi = [P^2 f^2(K_0 + K, a+b) - (r+\omega)K - r\beta K_0 - qb]\eta\}$.

The respective first order conditions are given by:

(14) $\Pi_K = P^2 f_K^2(K_0 + K, a) - (r+\omega) \leq 0 \rightarrow K = \tilde{K}^{**} \geq 0$; and

$$\left.\begin{aligned} &(15a)\quad \Pi_K = P^2 f_K^2(K_0 + K, a+b) - (r+\omega) \leq 0 \\ &(15b)\quad \Pi_b = P^2 f_b^2(K_0 + K, a+b)] - q = 0 \end{aligned}\right\} \rightarrow \mathrm{K} = \tilde{\mathrm{K}}^* \geq 0, b = \tilde{b}^* > 0.$$

The optimal farm level profits with $\theta = 0$ and $\theta = 1$ are thus given respectively by

(12a) $\tilde{\Pi}^{**}(\tilde{K}^{**}) = P^1 f^1(K_0, a) + [P^2 f^2(K_0 + \tilde{K}^{**}, a) - (r+\omega)\tilde{K}^{**} - r\beta K_0]\eta$, and

(13a) $\tilde{\Pi}^*(\tilde{K}^*, \tilde{b}^*) = P^1 f^1(K_0, \mathrm{a}) + [P^2 f^2(K_0 + \tilde{K}^*, a + \tilde{b}^*) - (r+\omega)\tilde{K}^* - r\beta K_0 - q\tilde{b}^*]\eta$.

Assuming internal solutions for the optimization problems in (12) and (13) we can compare $\tilde{K}^{**}$ with $\tilde{K}^*$. For this comparison it is useful to calculate the first order condition in (15a) at $K = \tilde{K}^{**}$:

(15a)' $P^2 f_K^2(K_0 + \tilde{K}^{**}, a + \tilde{b}^{**}) - (r+\omega) = P^2 f_K^2(K_0 + \tilde{K}^{**}, a + \tilde{b}^{**}) - P^2 f_K^2(K_0 + \tilde{K}^{**}, a) > 0$.

The inequality in (15a)' results from the assumption that capital and land are complementary inputs, (namely $f_{Ka}^2 > 0$), and allows us to conclude that $\tilde{K}^* > \tilde{K}^{**}$. In other words, when the option to acquire land at period 2 is available, the farmer's capital investment at period 2 is higher than the optimal investment when such an option does not exist. It is also interesting to compare optimal investments in periods 1 and 2 under certainty. From derivations not shown here it can be concluded that if the shadow price of capital at period 1, $P^1 f_K^1$, is relatively high, [relatively low], and purchase of additional land is not possible, than optimal investment in period 1 only, (K^{**}), is higher [lower] than the optimal investment in period 2 only, ($\tilde{K}^{**}$).

Similarly, comparison between $\tilde{K}^*$ and K^* (which are optimal for $\theta = 1$) shows that if the shadow price of capital at period 1, $P^1 f_K^1$, is relatively high, [relatively low], and purchase of additional land is possible, then optimal investment in period 1 only, (K^*), is higher, [lower], than the optimal investment in period 2 only, ($\tilde{K}^*$).

Optimal Timing for Capital Investment

As mentioned above, option theory suggests that the certain information with respect to land availability in period 2, as compared to the uncertain information in period 1, may make it worthwhile postponing the investment to the second period. The choice of the optimal timing in the current analysis can be made via the following procedure. First, assume that investment is made at period 1 only and calculate the present value of expected profits $\hat{\mathrm{E}\Pi}(\hat{K}, \hat{b})$, (see (5a)). Then, assume that investment is made only in the second period, and compute the present value of expected profits by (see (12a) and (13a)):

$$(18) \quad \tilde{E\Pi}(\alpha, \tilde{K}^*, \tilde{b}^*, \tilde{K}^{**}) = \alpha\, \tilde{\Pi}^*(\tilde{K}^*, \tilde{b}^*) + (1-\alpha)\, \tilde{\Pi}^{**}(\tilde{K}^{**}).$$

At the beginning of period 1, the farmer has to decide whether to invest *ex-ante* $\hat{K}$ or, to wait for the second period and to invest *ex-post* either
$\tilde{K}^*$ (if $\theta = 1$) or $\tilde{K}^{**}$ (if $\theta = 0$). The last stage of the procedure is to apply the following decision rule:

$$(19) \quad \begin{array}{l} \text{If } \hat{E\Pi}(\hat{K}, \hat{b}) \geq \tilde{E\Pi}(\alpha, \tilde{K}^*, \tilde{b}^*, \tilde{K}^{**}) \rightarrow \text{ then invest in period 1,} \\ \text{If } \hat{E\Pi}(\hat{K}, \hat{b}) < \tilde{E\Pi}(\alpha, \tilde{K}^*, \tilde{b}^*, \tilde{K}^{**}) \rightarrow \text{ then invest in period 2.} \end{array}$$

The actual result of the comparisons in (19) depends on empirical specifications and data and is presented in Section 4.

3. Empirical model

In this section we derive the shadow price equations for buildings and land of individual farms in a representative sample of Dutch dairy farming. These shadow price equations are used to derive optimal land demand and investment in buildings. The shadow price equations are derived from a micro-economic profit model. Micro economic profit models have been applied frequently in the agricultural economics literature (see Shumway, 1995, for an overview). This also holds for the dairy sector in the Netherlands (see Boots et al, 1997). Models of Dutch dairy farming have to take into account that dairy farms have operated under a quota constraint since 1984.

Dairy farming is modeled by assuming that the farm produces two outputs; milk (z_0), which is subject to a supply constraint, and a composite of other outputs (e.g. beef) (q_1). Two variable inputs are used; purchased feed (q_2) and a composite of other inputs (q_3). Furthermore, five quasi-fixed inputs are distinguished; labor (z_1), land (z_2), buildings (z_3), machinery (z_4) and dairy cattle (z_5). The model also includes a time trend (z_6) representing technology and a dummy (z_7) allowing for a change in technology due to the introduction of milk quotas in 1984.

The symmetric normalized quadratic (SNQ) form is used as the empirical specification (Kohli, 1993; Oude Lansink and Stefanou, 1997) of the restricted profit function. The SNQ is a flexible functional form that allows for negative profit and for curvature conditions (convexity in prices) to be imposed globally. Another advantage is that the estimation results do not depend on the choice of a numeraire netput (as is the case for the also frequently used normalized quadratic). The SNQ takes the following form:

$$(20) \quad g(v_i, z_k) = \sum_{i=1}^{3} \alpha_i v_i + \frac{1}{2} w^{-1} \sum_{i=1}^{3} \sum_{j=1}^{3} \alpha_{ij} v_i v_j + \sum_{i=1}^{3} \sum_{k=0}^{7} \gamma_{ik} v_i z_k + \frac{1}{2} w \sum_{k=0}^{6} \sum_{n=0}^{6} \beta_{kn} z_k z_n + w \sum_{k=0}^{6} \beta_{kn} z_k z_7$$

The last term in the restricted profit function indicates that the quadratic term of the time dummy (z_7) is not taken into account. Symmetry is maintained by requiring

$\alpha_{ij}=\alpha_{ji}$ and $\beta_{kn}=\beta_{nk}$. Linear homogeneity in prices is imposed by the term $w=\sum_{l=1}^{3}\theta_l v_{lt}$, where θ_l are non-negative constants determined as the average shares of netput l (l=1,..,3) in total costs plus revenues. Additional restrictions $\sum_{j=1}^{3}\alpha_{ij}\bar{v}_j=0(\forall i=1,..,3)$ have to be imposed, in order to identify all parameters α_{ij}. Here, $\bar{v}_j$ is an arbitrary point of observation.

Netput equations (i=1,..,3) are derived using Hotelling's lemma

$$(21)\quad q_i=\alpha_i+w^{-1}\sum_{j=1}^{3}\alpha_{ij}v_j-\frac{1}{2}\theta_i w^{-2}\sum_{l=1}^{3}\sum_{j=1}^{3}\alpha_{lj}v_l v_j+\sum_{k=0}^{7}\gamma_{ik}z_k+\frac{1}{2}\theta_i\sum_{k=0}^{6}\sum_{n=0}^{6}\beta_{kn}z_k z_n+\theta_i\sum_{k=1}^{6}\beta_{kn}z_k z_7$$

Shadow price equations (k=0,..,6) are derived taking the first order derivative of the profit function with respect to the quantities of fixed inputs:

$$(22)\quad s_k=\sum_{i=1}^{3}\gamma_{ik}v_i+w\sum_{n=0}^{6}\beta_{kn}z_n \qquad k=0,..,6$$

Notice that shadow prices between farms depend only on differences in the level of quasi-fixed inputs.

The milk supply function for the period before the introduction of milk quotas is derived by using the first order condition for profit maximization: $-\partial g(\cdot)/\partial z_0=v_0$, with v_0 being the price of milk. Solving for z_0 yields:

$$(23)\quad z_0=-\frac{1}{\beta_{00}}\left[w^{-1}\left(\sum_{i=1}^{3}\gamma_{i0}v_i+v_0\right)+\sum_{k=1}^{6}\beta_{k0}z_k\right]$$

Data and Estimation

Data on specialized dairy farms covering the period 1973/74-1992/93 come from a stratified sample of farms keeping accounts on behalf of the Dutch Agricultural Economics Research Institute (LEI) farm accounting system. The data set used for estimation contains 9365 observations on 1961 farms. In the sample (very) small farms and non-specialized farms are not represented.

Data on variable outputs and inputs are measured as revenues and costs. Other output is an aggregate of revenues from marketable crops, beef and veal, and other animals. Other variable inputs consist of feed for animals other than dairy cattle, seeds, fertilizers, pesticides, contract work, veterinary services, fuel, energy and costs of other cattle. Fixed inputs are labor (hours), land (hectares), buildings, machinery and costs of dairy cattle. Other variables in the empirical model are a trend and a dummy allowing for a change in technology due to the introduction of milk quotas in 1984.

Tornqvist price indices were calculated for the composite variables (other output, feed input and other variable input). Implicit quantity indices were obtained as the ratio of value and the price index. The price indices vary over the years, but not over the farms, implying that the differences in the composition of a netput, or quality differences, are reflected in the quantity.

The system of equations (21) and (23) is estimated with additive error terms included prior to estimation. Every farm is assumed to have a farm-specific intercept, reflecting differences in farm characteristics (e.g. management quality and soil quality). A fixed-effects model explicitly accounts for this assumption. The necessary transformation for such a model can also be applied to an incomplete panel, like our data set. The profit function is not estimated along with the netput equations, since the intercepts of the netput equations appear as slope coefficients in the profit function. Including the profit function during estimation requires direct estimation of all farm-specific intercepts. Note that all parameters of the profit function are, however, identified in the netput equations.

The milk supply equation (23) is included during estimation in the period before the quota introduction, causing a difference in the number of observations across equations. In the pre-quota period, the quantity of milk can be related to the error term and an instrumental variable estimator must be applied. Endogenous variables are z_0, q_i (i=1,..,3), and all terms containing milk output (e.g. z_0z_0, z_0z_k). All exogenous variables are used as instruments. Error terms may be correlated across equations. Therefore, the estimation technique used is non-linear 3SLS (Judge et al., 1998, p.655). The covariance matrix of residuals used in estimating the system is corrected for the difference in the number of observations (Judge et al., 1988, p.462).

The estimation results that can be obtained from the authors show that about half of the parameters are significant at the critical 5 per cent level. Moreover, estimation results show that land and buildings (but also milk quota and machinery) are complements, as was assumed in the theoretical analysis presented in Section 2.

4. Simulations and results

From the estimated model the shadow price equations are derived for the quasi-fixed inputs (22). In the simulations[2] all netput prices and quasi-fixed inputs are kept equal to the level of 1992/93. The only exceptions are land and buildings; the optimal level of these inputs is determined using assumptions about the probabilities of the possibility of buying land in period 2 (see Section 2).

Simulation I Perceived biases toward non-optimal investment decisions

In the first group of simulations we assume that investment in buildings takes place in period 1 and that there is a probability of buying land in period 2. Because we

[2] Note that we simulate optimal investment decisions and thus do not test if the theoretical model can predict actual past behavior. There are a few reasons for this. First, farm-level data on land prices, probabilities, adjustment costs, discount and depreciation rates are not available for the sample. Second, we have an unbalanced data panel, so that farms stay in the sample for a limited number of years only, making it very complicated to follow their actual individual investment decisions. Finally, the paper is focused on the *potential* (rather than actual) effects of uncertainty regarding the possibility of acquiring land on the investment in buildings.

do not know the actual probabilities we simulate over a range of probabilities (α = 0; 0.25; 0.50; 0.75 and 1). The simulations consist of two mutually dependent steps. First, the shadow price of land for an individual farm in period 2 is set equal to the price of land (*q*) and the optimal land demand is calculated as a function of the investment level, *K* (see Section 2.2). We assume the price of land to be equal to the average shadow price in 1992/93. In a perfect competitive land market it can be shown that the average shadow price would indeed equal the land price. This implies that if initially the shadow price is lower than the average shadow price the farm wants to sell land. If the shadow price is higher it wants to buy land. Focusing on the impacts of uncertainty about the possibility of *buying* land on capital investment, farms that want to *sell* land are excluded from the analysis (see section 2.2). In the second step, the optimal investment in buildings in period 1, in combination with land demand in period 2, is determined. This is done by equating the shadow price of buildings to an exogenously set value, $Q = \omega + r(1+\eta+\eta\beta)$ (see (6), Section 2.2).

If the initial shadow price of buildings is higher than *Q* then the farm wants to invest. If the initial shadow price of buildings is lower than *Q,* and lower than the salvage value, then the farm wants to disinvest. If it is lower than *Q* but higher than the salvage value then the farm wants to keep the capital stock constant (the fixed asset theory). However, in the current analysis we do not consider disinvestment and therefore we keep the stock of buildings constant in the simulations. We assume *r*, the acquisition price of capital, to be equal to the 1992/93 interest rate, which was equal to 5%. The adjustment cost parameter ω is assumed to be equal to 1% (see Gardebroek and Oude Lansink (2001) for an estimate of this parameter). The real discount rate η equals 1/(1+r). So we assume the opportunity costs of capital for the farm to be equal to the interest rate. In reality this depends on alternative investment projects and expectations of the individual farmer. Finally, we assume β the rate of depreciation, to be equal to 4%. This is in line with assumptions made by the Dutch Agricultural Economics Research Institute. These assumptions lead to a Q equal to 11%. The two steps in the simulations are mutually dependent. So, higher investment in buildings increases the demand for land and vice versa.

After the optimal investment levels in combination with land demand under uncertainty are derived we examine whether the result in (9) holds, i.e. that uncertainty about the probability of buying land ($0 < \alpha < 1$) leads to higher investment as compared to a situation where the option to acquire land is ignored or not available ($\alpha = 0$). Next, we determine whether there is perceived under-investment or over-investment. This is done by comparing the actual*, ex-ante,* optimal investment level under uncertainty ($\hat{K}(\alpha)$) with the perceived optimal investment (see $\bar{K}(\alpha)$ in (10)), the weighted average of the optimal investment levels under certainty. If the actual optimal investment level is lower than the perceived optimal investment there is a false impression that we have under-investment. If it is higher we have the false impression of over-investment (see Section 2.4).

Simulation II Investing in period 1 or 2?

The second group of simulations consists of two separate steps. First, assuming that both investment and buying land take place in period 2, optimal investment, land demand and profits are determined. Because in period 2 there is certainty about the possibility of buying land this is done only for the probabilities

$\alpha = 1$ and $\alpha = 0$ (land demand can be either realized or not). The shadow price of land is again set equal to the average shadow price of land in 1992/93 ('the land price') to determine whether or not to buy land when $\alpha = 1$. The shadow price of buildings is set equal to $Q_1 = r + \omega$ (see (14) and (15a)) which equals 6%. Second, the optimal timing for investment is determined using (19). Specifically, if the weighted average of the profit under certainty about the possibility of buying land or not in the case of investing in period 2 (18), is higher (lower) than expected profit under uncertainty, in case of investing in period 1 (5a), then investing in period 2 (period 1) is optimal compared to investing in period 1 (period 2).

Results

Simulation I Perceived biases toward non-optimal investment decisions

In this simulation it is assumed that farms invest in buildings in period 1. First the farms buying land are identified and then, under different probabilities of buying land, the optimal level of investment is determined. Finally, it is examined whether there is perceived over-investment or not.

Table1 presents the number of farms in the sample buying land and their investment decisions (investing or keeping the stock of buildings constant). The percentage changes in profits are relative to the present value of profits (in both periods) in the absence of capital investment and land acquisition (i.e., K=b=0). The percentage changes in capital (buildings) and land endowment are relative to their respective levels in the base year 1992/93.

Table 1: Number of farms in the sample buying land in period 2 and investing or not investing in period 1, percentage change ($\Delta\%$) in profits, capital (buildings) and land endowment.

\Probability α	0	0.25	0.5	0.75	1
Farms buying land	213[1]	213	213	213	213
Farms buying land and not investing	167	166	163	161	157
$\Delta\%$ profit	0	0.29	0.56	0.83	1.01
$\Delta\%$ land[3]	0	42.18	41.96	41.74	40.23
Farms buying land and investing	46	47	50	52	56
$\Delta\%$ profit	3.08	3.43	3.73	4.18	4.85
$\Delta\%$ land[3]	-	31.27	35.11	38.95	46.95
$\Delta\%$ capital	95.10	102.11	106.44	114.64	121.03
$\Delta\%$ optimal capital[2]	-	104.58	110.53	118.20	-

1: Farms would buy land if they could.

2: Percentage change in capital in case the capital amount equals the weighted average of capital under certainty (α = 0 and α = 1), using the probabilities as weight ($\overline{K}(\alpha)$ in (10)).

3: Optimal land demand given the investment made under uncertainty.

Table 1 shows that of the 409 farms in the sample 213 would like to buy land (52.0%). From these 213 farms, 56 would like to invest in buildings in addition to buying land (26.3%). The finding that additional investment is not optimal for a large number of farms may, among other things, be the result of an *ex-ante* high investment made prior to the base year 1992/1993, where the (uncertain) option of buying or renting land was not realized. The relatively large increase in land indicates that many dairy farms are very much constrained by the amount of land. Moreover, since land and buildings are complements, investment in buildings leads to a higher land demand. Table 1 shows also that with an increase in the probability of the possibility of buying land a larger number of farms want to invest and the average amount of land demanded and investment in buildings increases. This is caused by the larger (expected) land demand in combination with the fact that buildings and land are complements. These results also hold for each individual farm and confirm the findings in (7) and (9). So, taking the probability of buying land into account leads to an increase in investment. Moreover, Table 1 shows that expected profits increase with the increase in the probability of buying land. So it can be concluded that a higher probability of the possibility of buying land leads to more farms investing, higher investment in buildings and larger farm-level profits.

Next, we have examined the role of the informational structure on land availability in explaining the impression of many observers that farmers' decisions are non-optimal. For this purpose, optimal investment levels under uncertainty, given a specific probability level (see $\hat{K}(\alpha)$ in (6)), should be compared with the weighted average of the optimal investments with probabilities $\alpha = 0$ and $\alpha = 1$ using the probability as a weight (see $\bar{K}(\alpha)$ in (10)). Comparing the lines $"\Delta\% \text{ capital}"$ and $"\Delta\% \text{ optimal capital}"$ of Table 1, relating to farms which buy land and invest, shows that the optimal investment level under uncertainty, $\hat{K}(\alpha)$, is lower than the weighted average investment level, $\bar{K}(\alpha)$, for all probabilities strictly larger than 0 and smaller than 1 (see $K^{II}(\alpha)$ in Figure 1a). This result also holds for each one of the individual farms. For farms that do not invest at low probability levels but do at higher probability levels the optimal investment level is also lower than the weighted average investment level (see Figure 1b) at a specific probability. So, if there is a positive probability of buying land, farms invest more than they would when $\alpha = 0$. However, if farms actually buy land in period 2 there is the false impression that investments made in period 1 are too low.

Using (8) the extra expected profit the average farm would have in the case of full information is also calculated, where the full information case is the weighted profit at probabilities 0 and 1 using the probabilities α and $(1-\alpha)$ as weights. This extra profit would be the maximum price the farmer is willing to pay for full information. The expected extra profits under the probabilities (α) 0.25, 0.5, and 0.75 are 473, 1988 and 1552 EUR[3], respectively.

Simulation II Investing in period 1 or 2?

In the second simulation investment is made in period 2. The results are presented in Table 2 which shows the number of farms buying land, their decisions with respect to investing in buildings, and the percentage change, compared to 1992/93, in capital, land and profit (discounted over periods 1 and 2). It also shows the number of farms for which investing in period 2 is more attractive than investing

[3] 1USD = 1.10 EUR

in period 1. These numbers are determined using (19) in which the profit associated with investing under uncertainty in period 1 is compared to the profit obtained when investment is made *ex-post*, in period 2.

Table 2: Number of farms in the sample buying land in period 2 and investing or not investing in period 2, percentage change (Δ%) in profits, capital (buildings) and land endowment.

\Probability α	0	1
Farms buying land	210	210
Farms buying land and not investing	169	143
Δ% Profit	0	0.95
Δ% Land	0	39.60
Farms buying land and investing	41	67
Δ% Profit	1.48	4.09
Δ% Land	-	70.56
Δ% Capital	90.97	180.93
Number of farms for which investing in period 2 is more attractive than investing in period 1 (eq. (18)):		
α=0.25	6	
α=0.5	9	
α=0.75	10	

Comparison of Tables 1 and 2 shows that in the case where $\alpha = 1$ slightly fewer farms would buy land in period 2 if investment decisions are made in period 2 instead of period 1 (210 instead of 213). However, more farms invest in buildings (67 instead of 56). The average farm investing in period 2 buys more land and invests more in buildings, as compared to the average farm investing in period 1, but profits increase less. Moreover, investment and land demand are higher for 64 out of 67 farms and for three farms investment and land demand are smaller. These results can be explained by the fact that the shadow price of buildings in period 1 is relatively low (see (17)) when the purchase of land is possible.

Next we compare profit levels for individual farms purchasing land, in the case investments are made in period 2, to the profit levels of the same farms when investment in period 1 takes place under uncertainty. Table 2 shows that for most farms profit is higher when investment takes place in period 1 under uncertainty (α=0.25, 0.5 or 0.75) compared to profits in the case of investing in period 2 (see (19)). Comparing the profit levels for the average farm investing in Tables 1 and 2 can be misleading because it does not refer to exactly the same farms. These results clearly indicate that for most farms investing in period 1 under uncertainty is preferable to investing in period 2 under certainty about the possibility of buying land.

5. Summary and Concluding Remarks

Uncertainty about the possibility of acquiring land can be rather large in the EU for sectors like dairy farming. Farm-level investment decisions are commonly made *ex-ante* when the farmer is not certain about the possibility of purchasing land. This possibility is realized only in a future period. In this paper, we have developed and applied a simple two-period model in which a profit-maximizing farmer, facing uncertainty about the possibility of acquiring land, had to choose the optimal mix of capital (buildings) investment and land endowment. We have shown that commonly "observed" biases towards non-optimal investment decisions are not necessarily justified. Rather, these perceived biases may be the result of evaluating investment decisions without reference to the uncertainty associated with the possibility of acquiring land.

Observers who inspect farms for which the option of acquiring additional land was actually realized (not realized) in the “future period” (period 2) may conclude that actual investment made in the previous period (period 1) is too low (too high). These observations may be correct *ex-post*, but they do not necessarily demonstrate that, *ex-ante*, farmers make non-optimal or biased investment decisions. Empirical analysis of Dutch dairy farms shows that the optimal (*ex-ante*) level of investment in buildings under uncertainty is lower than the weighted average of optimal investments made under the assumption of perfect information.

Another important implication of the model is that potentially, farm-level capital investment in period 1 and the subsequent level of land purchased (when available) in period 2, may be strongly affected by the farmer's perception of the likelihood of land availability. Indeed, the empirical results show that with an increase in the perceived probability of purchasing land, a larger number of farmers choose to invest and both the amount of land demanded and the investment in buildings increase on each individual farm.

A working hypothesis of our analysis is that investment decisions must be made *ex-ante* (at period 1) when the farmer is not certain regarding the possibility of buying land. However, as suggested by the option theory, it might be beneficial to postpone investment until the second period when information regarding land availability becomes certain. We investigate whether postponing investment until period 2 is profitable or not and under what conditions. The empirical analysis clearly demonstrates that for the vast majority of Dutch dairy farms analyzed, *ex-ante* investment in period 1 is preferable to *ex-post* investment in period 2.

The results of our study are obviously subject to some qualifications. Land availability is assumed here as the only source of uncertainty that affects investment decisions. Inclusion of additional uncertainties with respect to prices, public policies and/or technology is another direction into which the analysis can be profitably extended. The two-period model is specialized, mathematically tractable and captures the major characteristics of the problem analyzed. However, it cannot fully capture the actual dynamics of investment decisions, the timing of varying parameters and continuous changes in capital stocks. Using a more complicate, multi-period or continuous stochastic dynamic optimization model may also benefit the analysis. The model presented here can serve as a building block in this type of extended analyses.

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