Farm Forestry Investment in Ireland Under Uncertainty

EMILY WIEMERS
Teagasc, Dublin

JASMINA BEHAN
FÁS, Dublin

Abstract: This paper develops a model to explain farmers' decision to move from agricultural activities to forestry. Farmers in Ireland have strong links with land and are reluctant to enter into forestry even when the returns from it exceed those from farming. This paper examines whether the reluctance among farmers to plant forestry originates in the nature of forestry investment, which is characterised by the irreversibility of the decision, the uncertainty about future returns, and the ability to delay investment in forestry. In this paper we use a real options method and focus on the contribution of uncertainty in returns and costs to the decision to invest in forestry.

I INTRODUCTION

In this paper, we explore farmers' reluctance to plant forest on agricultural land, even when the economic incentives, expressed as the net present value (NPV) of future revenue streams, are apparent. We augment the traditional NPV analysis by developing an options framework to describe how farmers make decisions about land use. In our analysis the farmer is a firm facing an investment decision, a firm that has assets and chooses the best use of these assets given its knowledge of product markets and related costs. In this analysis, the farmer's behaviour, which at first appears contrary to his best interests, is shown to be rational.

There are many methods by which firms make investment choices. The most common approach is to determine the NPV. If the NPV is positive, the 'NPV rule' says to invest in the project until the marginal return from capital is equal to its marginal cost. In practice, the NPV rule is often modified. Many

firms require that the rate of return from a project, called a hurdle rate, is greater than the cost of capital. Hurdle rates in excess of the cost of capital imply that the NPV rule is underestimating the costs of the project by ignoring the downside risk of the investment decision.

Dixit (1989a, b) and Dixit and Pindyck (1994) develop a different method of valuing investment. The methodology, called real options valuation, is based on the method used to value financial options. Real options valuation models liken investment decisions to financial call options, assuming that in order to act as a trigger for investment, the discounted revenue from the project must be sufficiently high to offset the sunk cost as well as the downside risk associated with future revenue streams. Unlike NPV models, real options models account for irreversibility, uncertainty and the value of waiting – features that characterise most investment decisions. When applied to firm investment decisions, real options models elucidate the difference between the observed hurdle rates in firm decisions and those implied by the NPV rule.

More recently, real options have been used to address issues regarding changes in agricultural land use. Capozza and Li (1994) examine the conversion of vacant land to urban uses and the conversion of developed residential land to commercial use. Tegene *et al.* (1999) use this framework to address the conversion of agricultural land to urban use. We expand on the Tegene methodology to examine the conversion of agricultural land to forestry in Ireland under price and cost uncertainty. We compare the revenues from forestry necessary to trigger investment implied by the options method to current forestry revenues to explore whether the options framework can explain the observed reluctance of farmers to plant forests.

The paper proceeds in the following manner: we describe the rules associated with forestry investment. We outline the options model used to analyse forestry in Ireland. We apply the model to Irish data and estimate the trigger point for investment in forestry under current conditions. Finally, we explore the impact of the recent reform of the EU Common Agricultural Policy (CAP), which breaks the link between agricultural subsidies and production, on forestry investment in Ireland.

II FORESTRY IN IRELAND

In recent years, forestry investment has been identified as a method to promote social and economic development in rural areas of Ireland. The Irish forestry policy emphasises the importance of private planting and gives farmers a central role in the expansion of the national forest cover

(Department of Agriculture, Food and Forestry (DAFF), 1996). In order to encourage farmers to consider forestry as an alternative farm enterprise, the government has introduced a series of afforestation grant and premium schemes. The grants are funded jointly by the European Union and the Irish government. They were introduced under the assumption that an improvement in returns from forestry relative to returns from traditional agricultural enterprises would be a sufficient incentive to encourage conversion of agricultural land into forest. Although farmers' involvement in forestry has grown from negligible levels in the early 1980s to 92 per cent of total planting in 2001, the increase has not been sufficient to achieve the planting targets of 20,000 hectares per annum outlined in policy statements (DAFF, 1996).

Behan (2002) has shown that in 2001, at the aggregate level, the NPV of forestry returns in Ireland exceeded that of beef and sheep enterprises in all regions, particularly in the western regions of Ireland. The NPV analysis implies that there should have been a greater uptake of farm forestry than that which occurred. Other qualitative studies have suggested that economic returns' ratios alone are not sufficient to capture the complexity of the decision-making process of individual farmers considering on-farm forestry (Ni Dhubhain and Gardiner, 1994; Gillmor, 1998; Frawley and Leavy, 2001).

One reason that returns' ratios may not be sufficient to model investment decisions about forestry is that forestry investment in Ireland is an irreversible decision and has a large sunk cost. Under the current regulations, planted land on which the premium is claimed is bound in forestry in perpetuity. Farmers investing in forestry agree to exchange agricultural returns on their land for the relevant forestry premium and planting grants. The premia are paid for 20 years and vary with the type of plantation. Broadleaf plantations qualify for a higher premium than conifer plantations but because conifers, particularly Sitka Spruce, grow well in the Irish climate, they form the most common type of plantation in Ireland. The premia are paid under the condition that the land will be permanently converted to forestry. If the trees are removed, the premia and planting grants must be repaid in full. Because planting grants cover the cost of planting, there is not an explicit sunk cost in the forestry investment. However, since the price of agricultural land tends to exceed that of afforested land, the conversion of agricultural land to forestry leads to an irreversible sunk cost equal to a reduction in the land value. Because the decision to invest in forestry can be delayed, farmers can choose the timing of forestry investment to maximise returns while reflecting the lower price of forestry land and the uncertainty over future revenue and cost streams.

III FORESTRY INVESTMENT UNDER PRICE AND SUNK COST UNCERTAINTY

In this paper we use real options to determine the optimal investment point for a farmer considering forestry. We specify the problem by assuming that returns from forestry and land prices are stochastic. Under these assumptions, the farmer faces an investment decision under returns and sunk cost uncertainty. In this section, we describe the model, we apply it to Irish data and finally we explore how changes in assumptions impact on the results.

3a. Model

Let A be the net returns from agriculture per hectare and B be the net returns from forestry per hectare. The value of B is determined by the market price of timber and the value of subsidies on forestry planting. We assume that A remains constant while B evolves stochastically. This assumption is based on a comparison of family farm income per hectare for drystock farms from the National Farm Survey 1998-2000 (Burke, *et al.*, 1998, 1999; Connolly *et al.*, 2000). Let V(B) be the value of the investment whose cash flows are equal to B and let F(V) be the value of the option to invest in V(B). A farmer considering investment in forestry wants to maximise the value of the investment opportunity or the option to invest, denoted by F(V).

We approximate the motion of B using a geometric Brownian motion with drift as follows:

$$dB = \alpha_B B dt + \sigma_B B dz_B \tag{1}$$

A geometric Brownian motion process is one that is lognormally distributed with a variance that grows linearly with time. Over any small time interval Δ_t, the change in B is normally distributed with mean $\alpha \Delta_t$ and variance $\sigma^2 \Delta_t$.

Investing in forestry requires paying a cost L, equal to the difference between the value of forestry land and the value of agricultural land. Investing in forestry also requires foregoing returns from agriculture. We specify the entire sunk cost K, equal to discounted agricultural returns plus the land price differential as a geometric Brownian motion as follows:

$$dK = \alpha_K K dt + \sigma_K K dz_K \tag{2}$$

Therefore, the option to invest must be the maximum of the expected value of the payoff from investing, discounted from the time of investment to the present:

$$F(V) = \max \{E((V(B_T) - K)e^{-\rho T})\} \qquad (3)$$

where $V(B_T)$ is the value of the forestry project at the time of investment, T, ρ is the appropriate discount rate and r is the risk free rate used to discount returns from agriculture. We assume that $\rho > \alpha_B$ so that waiting is not always the optimal policy. We want to solve Equation (3) and find the levels of B and K such that it is optimal to invest given the parameters specified in Equations (1) and (2).

In the same manner, we follow Dixit and Pindyck (1994) and use a dynamic programming approach to find the optimal investment region. This region is a combination of the value of B and K that makes it optimal to pay K to receive the returns of the project whose value depends on B. We separate the regions of B and K in which it is optimal to invest from those in which it is optimal to wait. In the region in which it is optimal to invest, the value of the project depends only on B as K is a once-off sunk cost. We find the value of the live investment in this region by first determining the value of the project as a function of the underlying variable, B. To do this we split the value of the investment into today's profits and the expected value of tomorrow's profits as follows:

$$V(B) = Bdt + E\{V(B + dB)\, e^{-\rho dt}\} \qquad (4)$$

Expanding the RHS using Ito's Lemma, dividing by dt and taking the limit as $dt \to 0$ yields the following differential equation:

$$\frac{1}{2}\, \sigma^2 B^2 V''(B) + \alpha B V'(B) - \rho V(B) + B = 0 \qquad (5)$$

Dixit and Pindyck (1994) show that the solution to this equation when bubble solutions are ruled out, is just the expected present value of the profit stream, $V(B) = \dfrac{B}{\rho - \alpha_B}$.

In the same manner, we derive the following partial differential equation for $F(B, K)$ which is valid over the region where it is not optimal to invest:

$$\frac{1}{2}\, \sigma^2{}_B B^2 F_{BB} + \frac{1}{2}\, \sigma^2{}_K K^2 F_{KK} + \sigma_B \sigma_K \gamma BK F_{BK} + \alpha_B B F_B + \alpha_K K F_K - \rho F = 0 \quad (6)$$

and where the subscripts of F denote partial derivatives of F(B,K). We can use the following boundary conditions to solve for B and K:

$$F(B, K) = V(B) - K = \frac{B}{\rho - \alpha_B} - K \qquad (7)$$

$$F_B(B, K) = V_B(B) = \frac{1}{\rho - \alpha_B} \qquad (8)$$

$$F_K(B, K) = V_K(B) = -1 \qquad (9)$$

The first condition states that at the optimal investment point, the value of the option must equal the value of the investment. The second and third conditions state that at the optimal investment point, the first derivative of the option value must equal the first derivative of the value of investment. The conditions are referred to as value-matching and smooth-pasting. The condition of value-matching means that at the trigger point of investment the value of the option must be equal to the value of the active project taking into account the sunk cost incurred in investing. The smooth-pasting condition requires the option and investment functions to meet smoothly. If this condition were not met there would be a kink at the trigger point. This kink would make it possible for the investor to raise the expected payoff by deviating from the supposedly optimal trigger point. If the kink were convex, the investor could obtain a higher expected payoff by entering strictly above the trigger point. However, if the kink were concave, continuation along the original value function would yield a higher payoff than switching. In either case, a kink necessitates that the optimal trigger point is not indeed optimal. In this case, there is one value-matching condition and two smooth-pasting conditions.

These boundary conditions should yield a solution to Equation (6), however these solutions are difficult to reach. To simplify the problem, we follow Dixit and Pindyck and reduce the problem to one dimension by noting that the optimal decision depends on the ratio between B and K rather than on their explicit values. Letting b equal the ratio between B and K, we can say the following:

$$F(B, K) = Kf(B \ / \ K) = Kf(b).$$

Finding the partial derivatives of the new function f and substituting them into Equation (6) yields the following differential equation:

$$\frac{1}{2} \left(\sigma_K^2 - 2r\sigma_B\sigma_K + \sigma_B^2 \right) b^2 f''(b) + (\alpha_B - \alpha_K) \, bf'(b) + (\alpha_B - \alpha_K) f(b) = 0 \qquad (10)$$

with the following boundary conditions $f(b) = \dfrac{B}{\rho - \alpha_B} - 1$, $f'(b) = \dfrac{1}{\rho - \alpha_B}$, and $pf(b) - bf'(b) = -1$. These conditions are exactly analogous to Equations (7) – (9). Solving in the same manner as before, we find the following optimal investment point for b:

$$b^* = \frac{\beta_1}{\beta_1 - 1}\,(\rho - \alpha_B), \tag{11}$$

where β_1 is the root of the following quadratic equation that is greater than 1:

$$\frac{1}{2}\left(\sigma_B^2 - 2\gamma\sigma_B\sigma_K + \sigma_K^2\right)\beta(\beta - 1) + (\alpha_B - \alpha_K)\,\beta + (\alpha_K - \rho). \tag{12}$$

3b. Irish Example

In this section we use empirical data to identify the trigger point for forestry investment in Ireland while accounting for uncertainty over forestry returns and land price sunk costs. We first use historical data on forestry returns, agricultural returns and land prices in Ireland to estimate the drift and volatility parameters, α_B, α_K, σ_B and σ_K which are used to approximate the motion of B and K. We use these parameters to derive the optimal level of forestry returns that trigger investment.

Figure 1 shows annual forestry returns for the period 1986-2001. The series trends upwards over time with one large increase. In 1994, the government raised the forestry premium by 155 per cent to encourage farm forestry; the large increase in the series corresponds to this policy change.

Figure 1: *Forestry Returns*
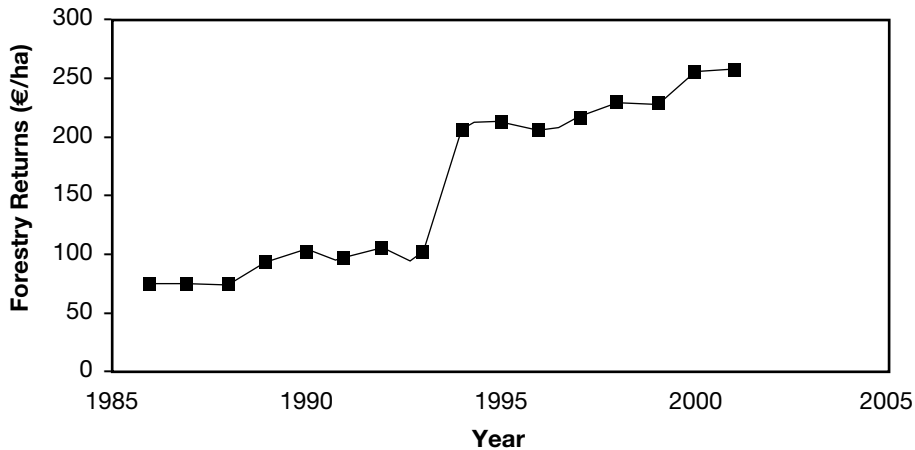
Source: FAPRI-Ireland model, 2002.

Using this data, we estimated a drift and volatility of 10 and 19 per cent respectively. These parameters were influenced strongly by the 1994 policy change. While historical data is the best available information for estimating the parameters governing the motion of forestry returns, it is important that the parameter choice accurately reflects farmers' expectations about future forestry returns. Given that an increase in the forestry premium of the magnitude experienced in 1994 is unlikely to reoccur, the data were transformed to reduce its effect on the drift and volatility parameters. After consultation with Irish forestry experts, the data were transformed by uniformly increasing all observations up to 1994 and consequently reducing the difference between the average level in the series prior and subsequent to the policy change. The drift and volatility parameters were reduced to 7 and 12 per cent respectively, a reasonable approximation of future expectations. The geometric Brownian motion is represented as follows:

$$dB = 0.07\ Bdt + 0.12\ Bdz.$$

The sunk cost was computed as the sum of discounted agricultural returns, A, and the loss of land value following forestry investment, L. The value of A was assumed to be the average family farm income per hectare for drystock farmers adjusted for the opportunity cost of labour (Connolly *et al.*, 2001). In Ireland, returns from drystock farming are the most suitable for sunk cost estimation because this system most closely competes with forestry for agricultural land. Returns from agriculture were assumed to be constant. Agricultural returns were adjusted downward to account for the greater labour intensity of drystock systems over forestry. The opportunity cost of labour was calculated by applying current minimum wage rates to the spare hours available to farmer foresters as opposed to a drystock farmer (Teagasc, 2002). Agricultural returns were discounted at 5 per cent.

We use historical data to approximate the motion of the land price differential. Figure 2 shows historical forestry and agricultural land prices, as well as their difference for the period 1982-2003 (Central Statistics Office, 2003, Kearney, 2002). While both agricultural and forestry land prices have been increasing for almost all of the sample period, there has been an upward movement of the land price differential, L, indicating a widening gap of the market value between forestry and agricultural land that peaked in 2001.

Based on the historical movement of the land prices and the value of agricultural returns, we generate drift and volatility parameters and define the evolution of the sunk cost as follows:

$$dK = 0.06\ Kdt + 0.14\ Kdz_K.$$

Figure 2: *Land Prices*
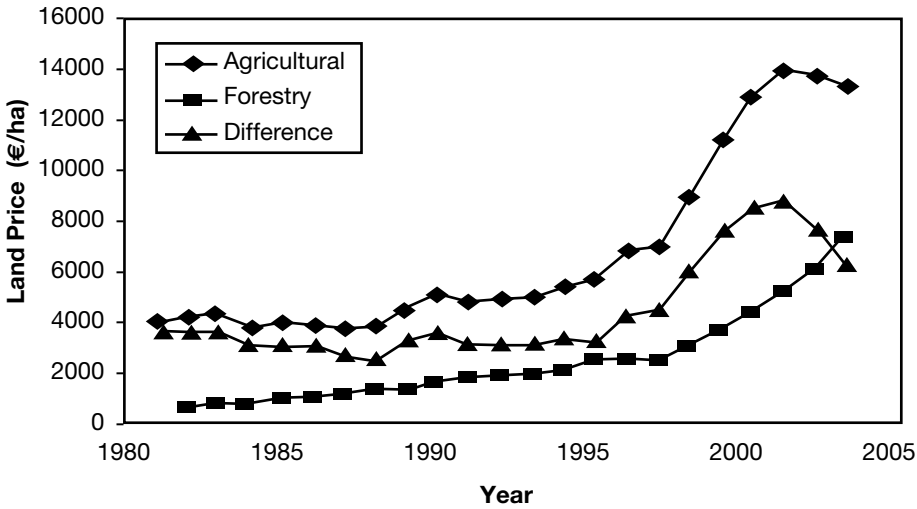
We assume a correlation of 5 per cent between forestry returns, B, and the sunk cost, K.

Using the outlined parameters, the optimal B/K ratio is 0.068. At current average land prices and agricultural returns, this ratio translates into an optimal trigger point, B*, of approximately 590 euros. The trigger point for forestry investment using the options method is higher than the forestry premium of 390 euros per hectare currently offered by the government. The result suggests that there is a value associated with waiting under current market and policy conditions and given the assumed motion of forestry returns and sunk costs. Moreover, in order to compensate farmers for uncertainty about future forestry returns, the premium would need to increase significantly.

Because both agricultural returns and land prices vary quite widely across the country, we also calculate the optimal value of forestry returns implied by different values for land price and agricultural returns. Table 1 shows the optimal trigger point for forestry investment under different land price and agricultural returns' assumptions. Agricultural returns of €250 per hectare represent the return on poor land such as rough grazing land. Agricultural returns of €300 per hectare represent the average drystock system. Agricultural returns of €350 per hectare represent the return on commercial farms. The lowest land price differential of €2,000 per hectare represents the difference between forestry land and agricultural land in remote areas. The middle land price differential is the average across the country. The largest

land price differential represents the situation in areas close to urban centres.

Table 1: *Optimal Forestry Returns Under Varying Sunk Costs*

Optimal Trigger (€)		Agricultural Returns (Before Labour Cost Adjustment) (€)		
Land Price		72 (250)	122 (300)	172 (350)
Differential (€)	2000	**236**	304	374
	6141	**520**	**590**	658
	11000	855	923	**991**

Of these cases, the shaded cases are the most significant. We first consider rough grazing land in remote areas. In this case, the land price differential is lower than average as is the value of agricultural returns. We find that the optimal trigger point for forestry returns is €236 per hectare. Many farmers have already planted forestry on this type of land and in doing so acted optimally. Second, we consider commercial farms in remote areas. These farms have relatively high agricultural returns per hectare but have low land values. These farms would require a forestry return of €520 per hectare to trigger forestry investment. Most farms of this type have not invested in forestry. This analysis confirms waiting as the optimal choice. The third shaded box represents the average case as previously discussed. The final shaded box represents a commercial farm in an area close to an urban centre such as Dublin, Cork, Galway or Limerick. In these areas agricultural land prices have been driven in part by the development potential of agricultural land. Because forestry land is bound in perpetuity, it cannot be developed for residential use. For these farmers, the returns from forestry would need to increase by over 150 per cent to trigger investment in forestry.

3c. Comparative Statics

In this section we analyse how changes in parameter values effect the optimal B/K ration. We examine the drift and volatility parameters of B and K and the correlation between the two series.

Figure 3 shows the change in the trigger point for forestry investment at different levels of volatility of forestry returns. As expected, greater volatility increases the trigger point for forestry investment. An increase in volatility implies that future forestry returns are more uncertain and therefore have a greater downside risk. The forestry return that triggers investment under more uncertain conditions reflects the level of compensation required to undertake a riskier investment.

Figure 4 illustrates how the trigger point for investment changes with the drift parameter of forestry returns. A higher drift parameter reflects higher

future forestry returns and lowers the return that triggers investment. As expected, the prospect of higher forestry returns in the future translates into a lower level of returns needed to trigger forestry investment.

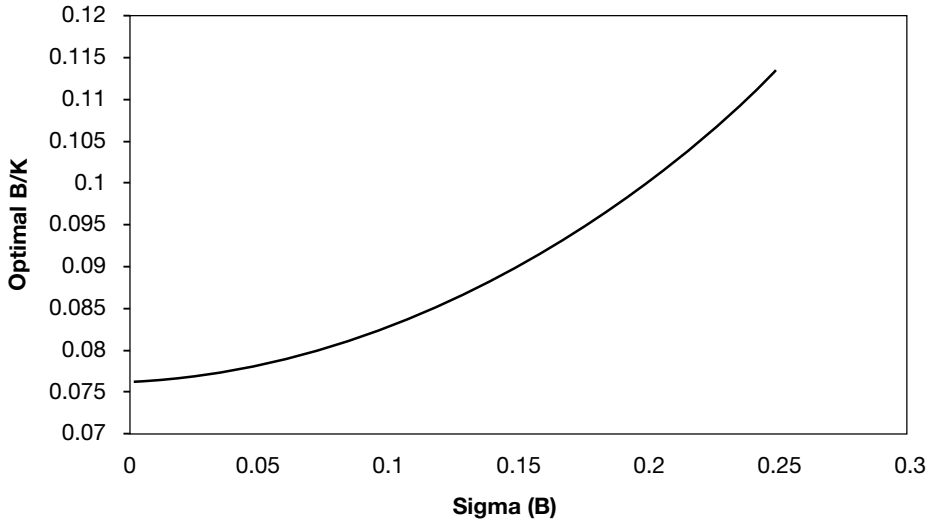Figure 3: *Optimal Investment Point and Forestry Returns Volatility* (σ_B)

Figure 4: *Optimal Investment Point and Forestry Returns Drift* (α_B)
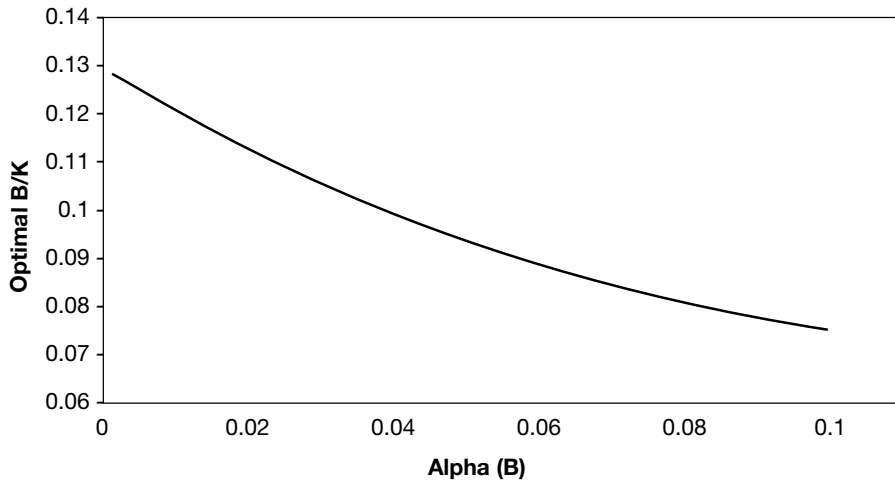

Figure 5 shows the change in the optimal B/K ratio with the change in the volatility of the land price differential. An increase in volatility of the land price difference increases the optimal B. High volatility makes waiting less

risky and deters investment because it implies more uncertainty about an increase in sunk costs in the future.

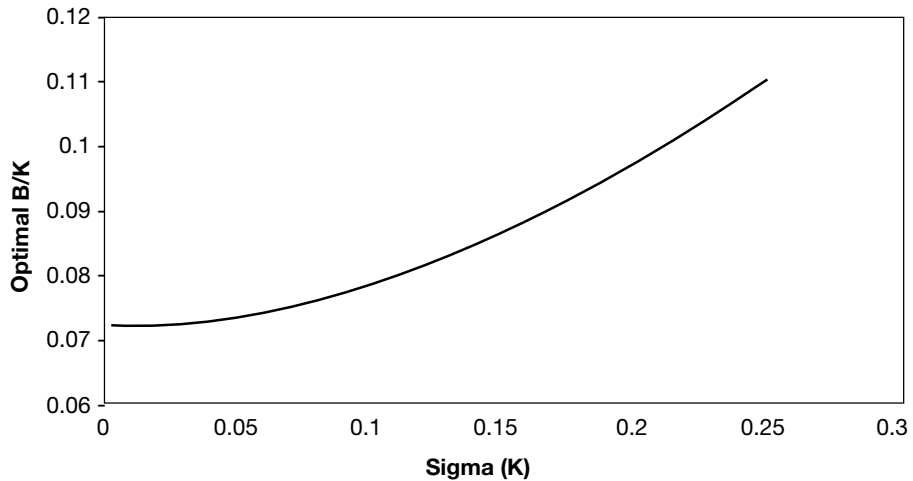Figure 5: *Optimal Investment Point and Land Price Volatility* (σ_K)

Figure 6 illustrates how a change in the drift parameter of the land price differential affects the optimal B/K ratio. As the drift of the stochastic process governing the land price difference increases, the optimal return at which forestry investment occurs is reduced because a higher sunk cost is expected in the future.

Figure 6: *Optimal Investment Point and Land Price Drift* (α_K)
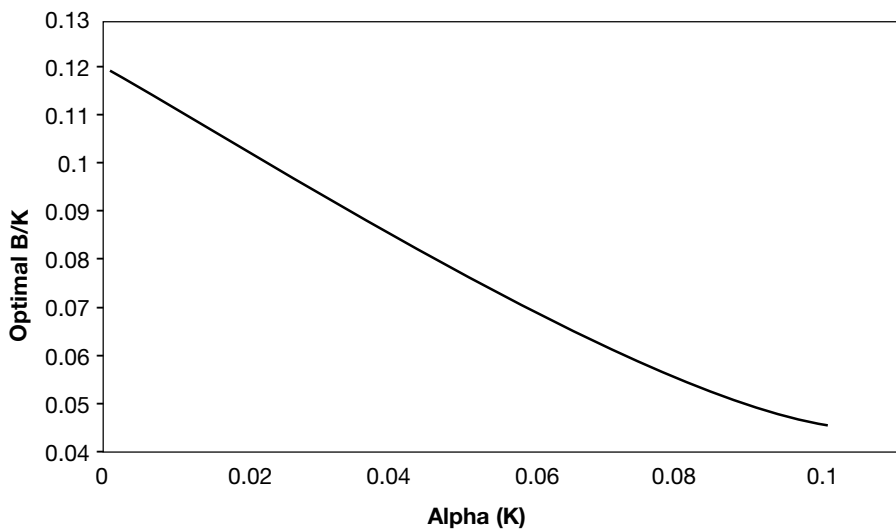
We assume that the correlation between forestry returns and land price differentials is negligible; the assumption implies that the underlying drivers for the two series are distinctly different. While the returns from forestry are primarily driven by world timber market developments and forestry policy, the evolution of the sunk cost in Ireland is primarily driven by the housing market. A high demand for new homes has driven average agricultural land prices up over the period, while leaving forestry land prices unchanged. The assumption can be relaxed allowing a higher correlation between the two processes. A higher correlation would reflect a belief that the future macroeconomic shocks would drive the evolution of both series. A higher correlation between B and K lowers the level of forestry return at which investment is triggered. A higher correlation reflects less risk about the future ratio between B and K and positively impacts investment timing by reducing the value of waiting.

IV IMPLICATIONS FOR DECOUPLING SCENARIO

Our analysis has shown that in the current Irish policy environment there is an incentive for most farmers to wait to invest in forestry. However, the agricultural policy environment in the EU and Ireland is changing because of the Mid-Term Review (MTR) of the Common Agricultural Policy. The proposals for the MTR were formalised in the Luxembourg Agreement in June 2003. One of the key reforms was to break the link between subsidies and production by allowing farmers to receive payments based on historical rather than current production. The reforms mean that farmers will receive a single farm payment in lieu of production related subsidies. Under the new policy, farmers will be able to plant forestry on up to 50 per cent of their land and claim the forestry premium along with their full single farm payment. In the future, farmers will make their decisions about farm forestry in an environment of fully decoupled single farm payments. In this section, we analyse the likely impact of these reforms on a farmer considering forestry as an investment option.

We specify this policy change by altering the sunk cost of investment to remove the subsidy portion of agricultural returns. As long as farmers do not plant more than 50 per cent of their land they will keep the single farm payment regardless of their decision about investing in forestry. Therefore, the sunk cost is made up of market returns from agriculture and the difference in value between forestry and agricultural land. The value of market returns from drystock farming after decoupling is difficult to quantify. In 2001, direct payment formed between 99 and 187 per cent of family farm income on drystock farms (Connolly *et al.*, 2001). Because the market returns from

farming are uncertain, we take two illustrative values: €0 per hectare to represent those farms which have low or negative market returns, and €100 per hectare to represent those farms which have high market returns. We use the land values outlined in Section III and apply the new decoupling rules to farms with both high and low market returns from farming. Table 2 shows the returns from forestry required to trigger investment in the various cases. For farmers whose land is less valuable, investing in forestry is optimal even if their market returns from farming are quite high. For farmers with average land values, investing in forestry is still not optimal, though for those farmers with low market returns, the forestry subsidy is nearly high enough to trigger investment. As was the case before decoupling, forestry investment is not optimal for farmers with valuable land.

Table 2: *Optimal Forestry Returns Under Varying Sunk Costs, Post-Decoupling*

Optimal Trigger (€)		Market Returns from Agriculture (€)	
Land Price		0	100
Differential (€)	2,000	137	274
	6,141	421	559
	11,000	755	892

For farmers whose market returns from agriculture are low, the difference between the value of forestry land and agricultural land can be up to €5,600 per hectare and it would still be optimal to invest in forestry at the current level of premium. For those with higher returns from agriculture, this number drops to about €4,000 per hectare. This analysis suggests that decoupling should have a positive effect on forestry planting.

V CONCLUSIONS

In this paper, we have applied a method used for corporate and financial investment decisions to land use decisions made by Irish farmers. We have analysed the decision to invest in farm forestry under returns and sunk cost uncertainty. Farmers would optimally invest when returns are high and sunk costs are low. We find that the value of forestry returns required to trigger investment is 590 euros per hectare given the current average value of the sunk costs. We have considered a range of sunk costs around the average and have shown that in most cases, there is still a value of waiting to invest in forestry. The only case in which investment is optimal is that in which the

difference between the value of forestry and agricultural land is low.

We have also used our model to examine the impact of the MTR of the Common Agricultural Policy on farm forestry investment in Ireland. The rules allowing farmers to claim their entire single farm payment and plant forestry on up to 50 per cent of their land makes investment in forestry more attractive. Our results suggest that forestry may become attractive to farmers for whom it had never been attractive in the past and that forestry investment overall may increase after decoupling.

The results suggest that economic factors are sufficient to explain some farmers' decision not to invest in forestry both under current and expected future conditions; farmers require compensation for the irreversibility of the forestry investment, particularly when returns are uncertain. We have shown that the NPV approach significantly undervalues the forestry returns' necessary to trigger investment and have highlighted the importance of accounting for uncertainty in analysing the farm forestry investment decision.

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