Risk Analysis and Stochastic Modelling of Agriculture

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Executive Summary

- This project analysed the role of risk in farmers' production decisions and the impact of policy changes on risk in agricultural production.
- A stochastic budgetary farm level model was developed using Irish National Farm Survey data and FAPRI-Ireland projections.
- The model was used to examine the varying level of farmers' exposure to risk under different policy regimes.
- Results showed that under the Mac Sharry and Agenda 2000 regimes of agricultural policy the major incentive for profit maximising farmers to engage in production was to qualify for direct income support. Direct payments were relatively risk free sources of income and therefore risk played only a minor role in the production decision. The results showed that farmers would be exposed to more risk under decoupling. The return to production post decoupling is market based only, as the direct payment is no longer linked to production, and therefore is more exposed to price and production risk.
- The stochastic budgetary model, which accounts for price and production risk, was used to estimate the economic trade off between "entitlement farming", that is retaining farm land only to claim payments and not produce any tangible products, and conventional farming.
- The results showed that for less efficient farms, the probability of achieving a significantly higher profit by engaging in entitlement farming is 46 percent, while further analysis shows that there is a 9 percent probability that profits from conventional farming systems would be only marginally higher than the 'entitlement farming' option.

The Role of Risk in the Decision to Produce Post-Decoupling – A Stochastic Budgeting Example

Introduction

Direct payments to agricultural producers in the EU were introduced after the 1992 Mac Sharry reforms of the Common Agricultural Policy (CAP). These payments were initially intended to provide compensation for income loss resulting from reduced intervention prices for the arable crop and beef sectors, but they soon became an very important feature of farming in Europe as the shift away from price support in favour of direct income support was advanced further in the Agenda 2000 agreement. For farmers throughout the EU direct payments became an important source of revenue in the late 1990s and early 2000s. The Medium Term Review (MTR) of the CAP has allowed for the decoupling of all direct payments from production from 2005 onwards throughout the EU. This means that farmers are no longer required to grow crops or stock animals in order to receive their direct payments contingent on good environemtnal practices. Hence, the decoupling of direct payments from production is likely to have significant ramifications for farm planning.

Over the last number of years plans designed to maximise farm profit have typically focussed on the maximisation of direct payments, so much so that the former EU Commissioner for Agriculture, Franz Fischler, declared '*that the policies have left farmers scouring the pages of the Official Journal of the European Communities instead of*

responding to market signals, and made small fortunes for consultancy firms offering subsidy-optimising software', (Fischler 1998). Production planning after the MTR requires a shift of focus. The emphasis must shift away from engaging in production to receive the subsidy. The focus should now be on the market based profit or as referred to here, the "coupled" returns to production, that is the profit excluding the decoupled payments. Under the new policy regime, when engaging in production planning, farmers and extension agents must also consider the relative profitability of the new farm system of "entitlement farming" that is the activity of retaining farmland solely for the purposes of receiving the Single Farm Payment without actually producing any tangible good.

The increased importance of risk in farm systems planning post-decoupling is the central focus of this paper. It is argued that prior to the MTR, farmers derived a large portion of their income from 'riskless' subsidies. While large portions of farm incomes will still be derived from subsidies, the decision to engage in production will be determined only by the 'coupled' returns to production. As the coupled returns to production are a function of a number of risky variables, the role of risk in farm planning will become more important. The paper begins by discussing the importance of risk in farm planning and outlining the argument that farmers' exposure to risk will increase post-decoupling. A background to stochastic budgeting is provided and its usefulness for farm planning is outlined. The decision to engage in production in the first year post-decoupling (i.e. 2005) is simulated for representative cereal producers, using data from the Irish National farm Survey (NFS) as a case study. A distinction is made between deterministic and stochastic projections

post decoupling. The results presented in this paper show the importance of considering risk when engaging in production planning post-decoupling. Our findings support the view that fewer farmers are likely to engage in production post-decoupling when risk is factored into the production plan, assuming the traditional assumption that farmers are risk averse.

Background

Risk is a fundamental component of agricultural production and various studies of farmers' attitudes to risk have generally found that farmers are risk averse (Chavas and Holt 1990 and Pope and Just 1991). It is therefore important that when preparing a farm plan that the risk of the production plan is considered and potential sources of risk and uncertainty are identified. While there are many sources of risk, they can be broadly separated into three main elements; institutional risk, production risk and economic risk, (Harwood *et al.,* 1999). Institutional or political risk refers to the risk of the policies and regulations governing the farming environment changing. Production risk refers to the inherent riskiness of the production process such as the variations in crop yields due to weather conditions or disease related risks affecting the output of livestock enterprises. Economic risk encompasses the volatility in output prices and input costs.

Under the Agenda 2000 and the Mac Sharry policies, farmers typically had two sources of profit coming from livestock and cereal production; market based profit and the coupled direct payment. The subsidy based revenue under this regieme was considered risk-free

and the market based margin was the only risky variable. Hence, in a policy environment where direct payments are coupled to production, a profit maximising farmer engages in production if total profit, that is market plus subsidy profit, exceeds the opportunity cost of the resources employed in the production process. In the late 1990s and early 2000s for many farms subsidy based profits exceeded the market based profits and therefore it made economic sense for farmers to engage in production even if they expected production costs to exceed output prices. However, from 2005 onwards in Ireland, direct payments are decoupled from production and farmers will receive these payments regardless of production levels. Therefore, farmers will have the option of engaging in 'entitlement farming', that is they do not have to produce any tangible output but can use the land to claim the decoupled payment. Under this policy regime, a profit maximising farmer will only engage in production if the market returns to production, i.e. market revenue less all variable costs, fixed costs and the opportunity cost of resources employed, exceeds returns to entitlement farming, that is the Single Farm Payment less compliance costs and fixed costs, (Breen, Hennessy and Thorne 2005).

It is clear then that when engaging in farm planning in a decoupled environment, the emphasis should be on maximising the market based gross margin. Over the last number of years, the role of risk in farm planning may not have been considered important because relatively risk-free subsidies comprised such a large portion of farm profit. It is argued here that the decoupling of direct payments will mean that farmers will have to give risk more consideration and in particular when designing a farm plan the farmer

should consider the risk of the market based return to production falling below the returns to entitlement farming and therefore eroding the value of the decoupled payments. A stochastic budgeting model is employed in this paper to illustrate the importance of considering risk in the decoupled agricultural environment.

Stochastic Budgeting and Farm Planning

The typical approach to farm planning involves developing forecasts of next year's yields, prices and costs based on either personal opinion or some published data (Lien, 2003). Typically these forecasts are then used to inform the decision making process and ultimately identify the farm enterprise mix that maximises farm profit. Hence, the reliability of these forecasts is key to the success of the farm plan. However, in reality '*the events and conditions planned for will not turn out as assumed'* (Lien, 2003, p.403). Stochastic budgeting is an improvement on this traditional approach as it involves attaching probabilities of occurrence to the possible values of the key variables in a budget, thereby generating the probability distribution of possible budget outcomes (Hardaker, Huirne and Anderson 1997). Hence, stochastic budgeting has particular relevance in the context of decoupled payments, when the returns from growing crops or rearing livestock, will continue to return 'non-normal' or 'non-average' results. Furthermore, the volatility in market based returns has the possibility of eroding the 'take home' value of the decoupled Single Farm Payment (SFP). The following section outlines the materials and methods used to examine the research hypothesis that the risk associated with crop production has the ability to erode the value of the SFP in a decoupled policy scenario.

Materials and Methods

The stochastic approach to farm budgeting post decoupling adopted in this paper uses two representative cereal farms producing spring feed barley: The first representative farm represents producers of average technical efficiency levels and the second represents producers of lower levels of technical efficiency, based on technical and financial data from the Irish National Farm Survey (NFS). The representative farms were selected based on relative gross margins received in 2003, for which the latest data was available from the Irish NFS. Gross margin was selected as the defining characteristic for this particular research question based on the assumption that relative gross margins post decoupling will be the primary variable on which production plans will be based (Breen *et al.*, 2005). Cereal production post decoupling is chosen as the representative farm type due to the variability in yield and prices that exist in these farming operations from one year to the next. Hence, production and economic risk are extremely important considerations for cereal producers. A summary of the key financial and technical descriptive statistics for the two representative farm groups are presented in Table 1.

<Insert Table 1 here>

The stochastic approach to projecting the returns to crop production post decoupling adopted in this paper incorporates the reality of risk into the projections. Hence, the stochastic market based margin forecasts post decoupling are presented as a range of

possible outcomes rather than point estimates. A 90 percent confidence interval can be placed around the 'mean' point estimates to show with 90 percent confidence what the gross margin return for each crop is likely to be in 2005, based on historic yield distributions[i]. This exercise identifies the upper and lower bounds of forecasted gross margins, which provides additional information to the traditional method of 'mean' deterministic forecasts (Lien, 2003).

While production risk in the form of yield variability is the key stochastic variable examined in this analysis, economic risk in the form of price volatility has also historically been considered a key risky variable in cereal production (McQuinn and Roche, 2003). However, in 2004 for the first time the emergence of a forward buying price emerged in the Irish cereals market, which to a large extent provides the opportunity to Irish producers to minimise economic risk (Thorne, 2004). Hence, for the purpose of this analysis, the forward buying price for spring barley was assumed to be 2.9% higher than the 2004 price, which accounts for the forward buying price and adjustments in projected moisture content. Furthermore, adjustments were in made for input prices, in line with projected inflation figures in 2005.

Since deviations from average yields in the era of decoupled payments are likely to have a greater impact on the decision to plant in a decoupled payment environment rather than a direct payment environment, the alternative farm profile scenarios defined in this analysis were: (i) the status quo of continuation of crop production

post decoupling and (ii) the entitlement farming option, where no crops are produced and the land is maintained in good agricultural and environmental condition subject to cross compliance regulations. The two representative cereal farms are examined to determine the probability that the average net margin per hectare from spring barley will be lower than entitlement values per hectare minus compliance costs, given the year to year variability in yield.

The stochastic model initially estimates probability distributions for yield, which is considered the key 'risky' variable in crop production[1]. The probability distribution is based on previous actual yields achieved over the past 10 years (based on Central Statistic Office estimates). Variability about the mean yield achieved over the time period is assumed as the stochastic component of the model.

The cropping decision trade-off analysis is based on the probability, from the stochastic model, that the projected net margin per hectare for cereal crop production could (i) be lower than the entitlement farming option; (ii) be between €1 and €25 per hectare greater than the entitlement farming option (defined as 'marginally' higher than the entitlement farming option); or (iii) be more than €25 per hectare greater than the entitlement farming option (defined as 'significantly' higher than the entitlement farming option). The estimated gross output for the entitlement farming

[1] The software computer program Simetar© developed at Texas A&M University is used for the computation of the stochastic projections.

option was based on the previously coupled direct payment of €383 per hectare less modulation and deductions for the national reserve. It is assumed that this output is also subject to cross compliance costs. Cross compliance costs are assumed to be similar to set-aside maintenance costs which existed pre deoucpling. It is assumed that a certain proportion of fixed costs are incurred under the 'entitlement' farming option and only quasi-fixed costs such as hired labour and machinery operating costs are disposed of under this farming option.

Results

This section presents the deterministic and stochastic projections for returns from spring barley production on two representative cereal farms (Table 2). In Table 2 the only variable assumed to be risky is yield. Accordingly, if the historical probability distribution for yield, denoted by $P(y_i)$, is as shown in Table 2, these also constitute the probability distribution for budgeted annual net return.

<Table 2 here>

Table 1 above shows that based on the historical yield distribution, the expected deterministic mean gross margin value for spring barley post decoupling is €518 and €358 per hectare for the average producer and the less efficient producer. These deterministic projections are based on the assumption of average yields achieved in

2005, and no probability is assigned to the occurrence of any other point estimate forecast except this average projection. However, it is evident from the distribution of gross margin estimates presented in Table 2 that reliance on deterministic projections neglects the potentially large influence yield variations can have on this projection. Hence, the rationale for using a stochastic projection in this scenario is highlighted.

To examine the stochastic outlook for crop production post decoupling, the projection for the entitlement farming option is also required. For the purpose of this analysis it is assumed that the returns to entitlement farming can be defined as follows:

$(E - CC) + FC^*$, where

E = Entitlement value per hectare minus cross compliance and modulation (€345)

CC = Cross Compliance Costs per hectare (assumed to be €74 per hectare)

FC* = savings in quasi fixed costs per hectare (€101 for 'average' producers and €79 for 'less efficient' producers).

Based on the above assumptions the returns from the entitlement farming option are estimated at €372 for the representative farm of average efficiency and €350 for the less efficient representative farm. Furthermore, considering that the Single Farm Payment is a decoupled payment and assuming that the associated cross compliance costs are not stochastic variables, this projection is assumed deterministic. Hence, based on a deterministic projection, the returns from entitlement farming for both the average producer and the less efficient producer are lower than the returns from crop

production. Figure1 addresses the same farm planning question using stochastic budgeting where the probability that (i) average net margins per hectare would be significantly higher than the returns from entitlement farming; (ii) average net margins per hectare would be only marginally higher than the returns from entitlement farming; and (iii) average net margins from cereal production would be lower than entitlement farming, post decoupling.

<Figure 1 here>

Figure 1 shows that there is a high probability (over 90 percent) that the returns from spring barley production in 2005, for the representative farm with average efficiency levels, will be higher than the returns from entitlement farming alone, given the variability in yields than can occur in any given year. The average spring barley producer who achieved an average yield of 7.5 tonnes per hectare in 2004, has a 94% probability that the returns from growing the crop in 2005 would be higher than the entitlement farming option. yields could vary in line with the histrionic distribution of these variables.

However, in the case of the 'less efficient' producer of spring barley there is a high probability that the net returns per hectare could be lower than the entitlement farming scenario in the era of decoupled payments. A spring barley producer that is less efficient than the average, with yields of 5.6 tonnes per hectare in 2004, has only

a 45 percent probability that the returns from the crop in 2005 would be higher than the entitlement farming option. Furthermore, there is a 46 percent probability that the returns from growing the crop would be lower than the entitlement farming option and a 9 percent probability that the margin over entitlement farming would be as low as €25 per hectare. Hence, given that spring barley is the most significant crop in the Irish cereals sector this finding could have significant implications for average net farm income, depending on the cropping decisions adopted.

Discussion and Conclusions

Risk is an intrinsic component in decision-making in all businesses but is even more important in agriculture because of the exposure to institutional and production risk. Information from deterministic projections based on the assumption of point estimates of uncertain variables may not tell the full story for the purpose of developing future cropping decisions since the probability distributions of certain outcomes are not considered. In particular, in the era of decoupled payments, the exposure to risk at farm level becomes all important in terms of the more important role of market based returns to production. In contrast in the era of coupled direct payments, it was economically rational for farmers to engage in market loss making enterprises in order to receive the direct payment. Under decoupling however, the continuation of existing farm profiles on certain farms could result in the unnecessary erosion of the value of the decoupled payment. Consequently, the role of risk in the

decision to engage in production is of increasing importance in the context of decoupling.

Based on the findings of this paper, it is evident that the resulting farm plans from deterministic versus stochastic approaches can yield significantly different results. Based on the deterministic approach to farm planning post decoupling, the returns to cereal production are higher than the entitlement farming option for the average and less technically efficient producers. However, when stochastic approaches are adopted, there is a high probability for the less technically efficient cereal producers that an unnecessary erosion of the value of the decoupled payment could occur, if they engage in the production of cereal crops. It is clear, that post decoupling these less efficient producers will have to reappraise their farm profiles. In particular, crop insurance programmes, such as those which are popular in the United States, could be considered appropriate for the afore mentioned producers, that are particularly vulnerable to production risk in the era of decoupled payments.

If a number of farmers opt for entitlement farming, there will be ramifications for aggregate cereal production and in turn for price. However, the extent to which these results will have implications for total area under production will depend largely on the risk averse nature of individual farmers. Research findings from Breen *et al.,* (2004), based on a deterministic profit maximisation model, indicate that just under 4 per cent of tillage farmers in Ireland would benefit financially by becoming 'entitlement

farmers' in 2005. However, depending on farmers' risk preferences, this figure could be significantly higher if farmers and extensions agents engaged in stochastic budgeting. Hence, it is hypothesised that the stochastic approach to farm planning outlined in this paper could assist farmers in the farm planning process post decoupling, given the specific risk aversion of individual farmers.

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TABLE 1 – Summary Statistics for Representative Farm Groups Based on Financial & Technical Data for 2003

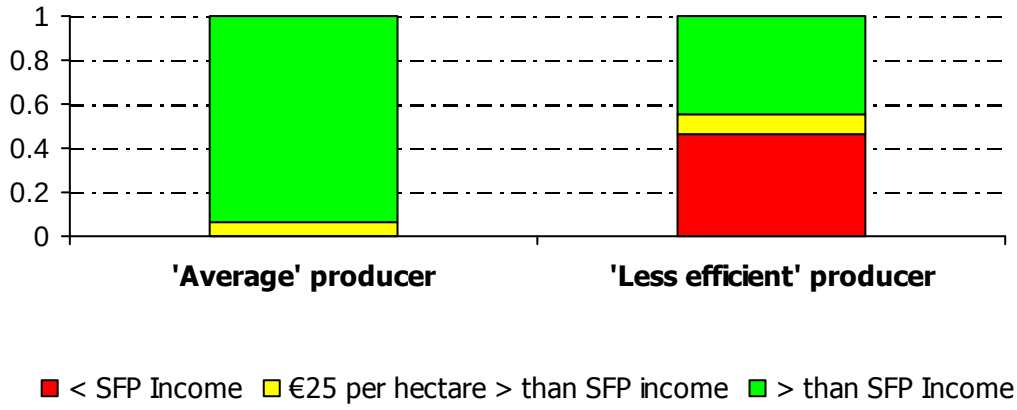
	Yield	Gross Output	Variable Costs	Gross Margin	Fixed Costs	% of Producers
'Average' producer	**4.69**	**384.4**	**193.7**	**154.7**	**67.2**	**25%**
'Less efficient producer'	**6.18**	**417**	**184.0**	**233**	**94.1**	**50%**

Source: National Farm Survey, Teagasc (2004)

Table 2 - Budget Assumptions for Spring Barley Production based on Yield as a 'Risky' Variable

Yields (tones per hectare)	**Probability of yield occurrence**	**Gross Output (€ per hectare)**	**Variable Costs**	**Gross Margin**	**Cumulative probability of net return**
Actual Values	*(P(y_i))*	*(GO)*	*VC*	*GM*	*(P(GM ≤ GM*))*
'Average' producer					
4.4	0.1	826	447	378	0.1
5.2	0.2	906	447	459	0.3
5.4	0.2	933	447	486	0.5
5.9	0.2	986	447	539	0.7
6.2	0.1	1013	447	566	0.8
6.7	0.1	1067	447	620	0.9
6.9	0.1	1094	447	646	1.0
'Less efficient' producer					
3.5	0.1	719	455	264	0.1
4.0	0.3	772	455	318	0.4
4.2	0.1	799	455	344	0.5
4.4	0.2	826	455	371	0.7
4.7	0.1	853	455	398	0.8
4.9	0.1	879	455	425	0.9
5.2	0.1	906	455	451	1

Figure 1: Probability estimates for net margins from cereal production versus '*entitlement farming*[2] on farms with varying levels of technical efficiency (2005)



[2] Entitlement farming is assumed to represent the farming situation whereby the land is used only to activate and draw down the SFP. No cereal crops are grown on the farm and the land is maintained in good agri - environmental condition.