Efficient allocation of land in a decoupled world

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Abstract

In this paper we investigate whether specialist producers of Irish cereals were allocating land efficiently in a mean-variance sense during the 1993-2002 time period. We then expand the model to examine the potential implications on the land allocation decision of the 2002 EU Commission's proposed mid-term reform of the Common Agricultural Policy. One-year ahead rolling forecasts of conditional moments of Irish cereal prices are generated using a multivariate autoregressive conditional heteroscedastic model. These forecasts are used to construct expected efficient frontiers for each year between 1993 and 2002. Our findings indicate that in every year specialist producers of Irish cereals were allocating land efficiently ex ante. We also show that the proposed introduction of decoupled payments will change the efficient frontier facing Irish cereal producers and probably induce producers to allocate more land to the higher returning yet relatively riskier wheat crop.

Keywords: Cereal Prices, Risk, Return, Multivariate ARCH

JEL classification: C32, F31, G15, Q14

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1. Introduction

The potential decoupling of agricultural support measures has had a heightened significance for European Union (EU) and world agriculture ever since the Uruguay Round Agreement on Agriculture in 1994. The publication in July 2002 of the EU Commission's proposed medium term review (MTR) of the Common Agricultural Policy (CAP) signaled an important evolution in the Commission's position on the decoupling of support measures (see DG-AGRI (2002)). Under both the McSharry (1992) and the Agenda 2000 (1999) policy reforms, producers have had to produce in order to receive direct payments i.e. the payments are coupled to production. This, together with the general reduction in cereal prices since 1993, has greatly altered the risk-return opportunities set facing producers. The MTR proposes to fully decouple the direct payments. This move could significantly change the constraints on the land allocation decision facing Irish cereal producers. Producers would now be in receipt of relatively large risk-free payments. As noted by Blank (2001) "if a risk-free investment exists, the opportunity set available to farmers is altered". Consequently, in this paper we ask two questions. The first is, given the major changes post McSharry, have specialist producers of Irish cereals been allocating land efficiently in a mean-variance sense over the period 1993-2002? The second is, if decoupled payments and cross-compliance costs were introduced in 2003 how would this alter the risk-return opportunities facing specialist producers of Irish cereals?

To answer these questions we estimate a version of the Roche and McQuinn (2002) multivariate autoregressive conditional heteroscedastic (MVARCH) model to compute rolling forecasts of the conditional means, variances and covariance of Irish cereal returns one year ahead for the 1993-2002 time period. Then, we use portfolio theory to calculate the annual expected efficient frontiers (or the opportunity set) facing specialist producers of Irish cereals and examine whether their actual land allocation was located on the expected efficient frontier.

Finally, following work by Tobin (1958) and Blank (2001) we expand the crop portfolio model to allow for risk-free decoupled payments. Many studies examine the effects of decoupling in the context of risk and uncertainty (see Hennessy, 1998, Anton and LeMouel, 2002, Sckokai and Moro, 2002a, and Sckokai and Moro, 2002b, for example). However, examining the role of risk-free (decoupled) payments within portfolio theory has the considerable advantage of not requiring any knowledge of producers' preferences vis-à-vis risk and return in order to determine the optimal allocation of land.

Our main findings are that specialist cereal producers were producing efficiently in a mean-variance sense in every year between 1993 and 2002. We show that the proposed introduction of decoupled payments will probably induce specialist producers of Irish cereals to allocate more land to the higher returning yet relatively riskier wheat crop. We estimate that if the decoupled payment were set about 32% higher than the cost of cross-compliance the optimal crop portfolio would result in 53% of land being allocated to wheat production. This is the typical percentage of land allocated to wheat production by specialist cereal producers in Ireland. We also estimate that if the decoupled payment were set about 80% higher than the cost of cross-compliance the optimal crop portfolio would result in 100% of land being allocated to wheat production.

The remainder of the paper is organized as follows. In Section 2 we present some basic portfolio theory. Portfolio theory is examined in the context of the EU Commission's proposed reforms of the CAP. In Section 3 we describe how the expected return, the variance of return and the covariance among returns to cereals production can be estimated using an autoregressive distributed lag model expanded to allow for time varying second moments. Some results and analysis are presented in Section 4. A final section offers conclusions.

2. Optimal farmland allocation

The use of portfolio theory in the determination of optimal land allocation is relatively popular within the literature. Newbery and Stiglitz (1981), Schaefer (1992), Hardaker et al. (1997), Hirschi (2000) and Blank (2001) amongst others have either presented or applied variations of portfolio theory in respect of land allocation decisions. In this paper, we use portfolio theory to ascertain whether specialist producers of Irish cereals were allocating land so as to maximize expected return for a given expected risk over the 1993-2002 period. Specialist producers in an Irish case tend to produce just two crops, barley and wheat. One could think of the farmer's decision to allocate land to barley and wheat as an investor's decision to create a portfolio comprised of two assets. The expected return and risk on a two crop portfolio is given as

$$E\left(R_P\right) = X_B \cdot E\left(R_B\right) + X_W \cdot E\left(R_W\right) \tag{1}$$

and

$$\sigma_P^2 = X_B^2 \cdot \sigma_B^2 + X_W^2 \cdot \sigma_W^2 + 2X_B X_W \cdot \sigma_{B,W} \tag{2}$$

respectively. Here R_P, R_B and R_W are the returns to the crop portfolio, barley and wheat, X_B and X_W are the weights (or percentage of land allocated to production) attached to each crop, σ_P, σ_B, σ_W are the standard deviation of returns to the crop portfolio, barley and wheat, and $\sigma_{B,W}$ is the covariance between returns on barley and wheat production. The X_i are non-negative and sum to unity.

The hyperbola in Figure 1 shows combinations of return and risk for different values of the crop portfolio weights. It is called the minimum variance frontier. We will examine two cases based on different expected returns, standard deviation of returns and covariance between returns on barley and wheat production. They are typical of frontiers we estimate using Irish data. In both cases we assume that barley has a lower expected return and risk than wheat and that the correlation between the return on barley and return on wheat is less than perfect[1]. The point B represents farmers who produce only barley and the point W represents farmers who produce only wheat. In the first case the minimum variance frontier BMW, in Figure 1, gives minimum risk for any expected return for different allocations of land to barley and wheat. The point M represents a combination of barley and wheat that offers the lowest risk to a producer. The weight attached to wheat at point M can be calculated by

$$\frac{\sigma_B^2 - \sigma_{B,W}}{\sigma_B^2 + \sigma_W^2 - 2\sigma_{B,W}} \tag{3}$$

The top half of the minimum variance frontier MW dominates the bottom half and is called the efficient frontier. The efficient frontier gives the maximum expected return for a given risk for various combinations of barley and wheat. For cereal producers to be allocating land efficiently in a mean-variance sense, they need to be choosing a point on MW. The farmer is allocating more land to the production of wheat as he/she moves up the efficient frontier from M to W. In the second case the point at which farmers who produce only barley is depicted at B^* in Figure 1. In this case the land allocation associated with M involves negative weights attached to wheat production, which we rule out. The least risk land allocation is at B^* and the efficient frontier is the curve B^*W.

In these two cases, we have implicitly assumed that there is no risk-free return available to farmers. Presently, producers in receipt of direct payments must produce or have an animal in production to receive the direct payment. Consequently, in the existing policy environment, these direct payments could not be construed as riskless. The presence of a risk-free income payment in the opportunity set of the producer gives rise to the separation theorem. This theorem developed by Tobin (1958) who used the mean-variance framework to state that all producers will have the same proportionate composition of products

[1] As it turns out, this is what is empirically found in Irish data.

regardless of their preferences. Therefore, in the presence of a risk-free return the optimal combination of risky assets for a producer can be determined without any knowledge of the producer's preferences towards risk and return. In this case the efficient frontier is linear.

Blank (2001) concludes that the presence of risk-free return allows the identification of the grain producers' "cropping opportunities line". The cropping opportunities line (COL_1) is a straight line commencing at the risk-free return per hectare on the vertical axis (RF_1) in Figure 2 and running tangential to the efficient frontier MW. As such, it constitutes the efficient frontier for a producer operating in the presence of a risk-free asset (such as the decoupled payment). It dominates the MW at all points except for the point of tangency, O, between COL_1 and MW. This point of tangency consequently represents the optimal portfolio, O, for the producer in such a new policy environment. The optimal land area allocations (weights) are given as

$$
\begin{aligned}
X_W &= \frac{[\bar{R}_W - R_F]\sigma_B^2 - [\bar{R}_B - R_F]\sigma_{B,W}}{[\bar{R}_W - R_F]\sigma_B^2 + [\bar{R}_B - R_F]\sigma_W^2 - [\bar{R}_W - R_F + \bar{R}_B - R_F]\sigma_{B,W}} \\
X_B &= 1 - X_W
\end{aligned}
\tag{4}
$$

Farmers choose a point on the efficient frontier RF_1-O-COL_1 depending on preferences. The crop portfolio land allocations to barley and wheat are always the same on this efficient frontier. What is different along RF_1-O-COL_1 is the total amount of land actually used in production. A specialist producer whose indifference curve is tangent at O will choose to plant crops on all of the land. If the indifference curve is tangent between RF_1 and O the farmer will choose to plant crops on a fraction of the land allocating land between barley and wheat in optimal proportions given at point O and leave the remaining land idle. If the indifference curve is tangent between O and the end of COL_1 the farmer will choose to lease land (if possible) and plant crops on all of the land, allocating land between barley and wheat in optimal proportions given at point O. If the producer is not able to lease extra land the efficient frontier becomes RF_1-O-W. In this case after point O the farmer allocates more (less) land to wheat (barley) production.

The Agenda 2000 reforms necessitated that member states of the EU lay out environmental requirements, which the resulting direct payments of that reform would be dependant upon. This issue is commonly referred to as cross-compliance. In the proposed MTR of the CAP, the new decoupled payments would be brought in "with reinforced cross-compliance conditions including land management obligations" (see DG-AGRI (2002)). This effectively would impose a cost on any producer who wished to leave land idle or out of production.[2] Presently, the exact cost is unknown. In Figure 2 we examine two cases, RF_1 is a case where the decoupled payment is small relative to the cost of cross-compliance and RF_2 is a case where the decoupled payment is large relative to the cost of cross-compliance. The lower the decoupled payment relative to the cost of cross-compliance the lower will be the risk-free return for the producer. In this case, the optimal crop portfolio will be nearer to M (the point of lowest risk) for the producer and the less wheat will be produced.

3. Conditional forecasts

In this section we describe how we generate the expected efficient frontier facing cereal producers at any planting time period. Forecasts of risk and return are required. In general producers of cereals face two types of risk, price risk and production risk. In this paper however, we assume that the only risk confronting producers is price risk, producers are assumed to be facing non-stochastic yields. This approach is very common in the literature (see Coyle, 1992, Saha, 1997, Coyle, 1999, OudeLansink, 1999, Boyle and McQuinn, 2001, and Sckokai and Moro, 2002a, for examples). While production/yield risk is significant, one

[2] Assuming that participation in production would satisfy cross-compliance regulations.

could argue that price risk is a relatively new phenomenon for EU cereal producers given the historical levels of intervention/guaranteed prices.

We follow Roche and McQuinn (2002) and forecast the conditional mean, variances and covariance of barley and wheat returns over the period 1993-2003 using a MVARCH model for Irish barley and wheat prices. They show that this time series model produces superior forecasts of expected return and risk for Irish feed barley and wheat than the commonly used method of Chavas and Holt (1990)[3]. The economic theory behind Roche and McQuinn (2002) is the simple law of one price. It is assumed to hold between British and Irish cereal prices.[4]

In Figures 3 and 4 we present the sterling prices of Irish and British wheat and barley prices. The Irish prices and exchange rates were obtained from monthly bulletins of the Irish Cereals Authority (CAI) whilst the British prices were obtained from the British Home Grown Cereals Authority (HGCA). The Irish prices are adjusted for monetary compensatory amounts.[5] The prices are monthly covering the period January 1982 to September 2002. It is apparent from Figures 3 and 4 that with certain exceptions Irish and British prices track each other quite closely. The results in Roche and McQuinn (2002) suggest that there is a long-run or cointegrating relationship between the Irish cereal price, the British cereal price and the punt/sterling exchange rate over the period January 1982 to September 2002. In order to

[3] See for example Oude Lansink (1999) who applied the Chavas and Holt (1990) forecasting methods to land allocation on Dutch arable farms

[4] Ireland's single largest trading partner in cereals is the UK.

[5] Monetary compensation amounts (MCAs) were introduced to compensate producers for unfavorable changes in their country's green rates. These amounts were applied at a country's frontier where they acted as a tax on exports from countries where farm prices were being kept low and a subsidy on those where prices were being kept high. The MCAs were to be phased out by gradually aligning the green rates on the market exchange rates. The application of the MCA system at the internal frontiers of the Community was incompatible with the introduction of the Single Market on the 1 January 1993. With the introduction of the Single Market, green rates were aligned on monetary rates, which resulted in only small monetary gaps. Thus MCAs were removed. The relevant MCA amounts were again obtained from the CAI's monthly bulletins.

capture some of the short-run movements in Irish cereal prices away from their long-run equilibrium values Roche and McQuinn (2002) estimate an error-correction model. They find ARCH effects in this short-run model and therefore allow for time varying variances and covariance in Irish barley and wheat prices using a MVARCH representation for the stochastic errors in the conditional mean model.[6]

Irish cereal producers typically harvest feed barley and wheat in August-October and plant in October. At the time they are deciding how much farmland to allocate to barley and wheat production, we assume that farmers form expectations with regard to the expected return and risk associated with each cereal twelve months ahead. Thus, for forecasting purposes the Roche and McQuinn (2002) error-correction model can be written in its linear autoregressive distributed lag form as

$$\begin{aligned} p^{wir}_{t+12} &= \alpha_0 + \alpha_1 p^{wir}_t + \alpha_2 p^{wir}_{t-12} + \alpha_3 p^{wuk}_t + \alpha_4 p^{wuk}_{t-12} + \alpha_5 e_t + \alpha_6 e_{t-12} + u^w_{t+12} \\ p^{bir}_{t+12} &= \beta_0 + \beta_1 p^{bir}_t + \beta_2 p^{bir}_{t-12} + \beta_3 p^{buk}_t + \beta_4 p^{buk}_{t-12} + \beta_5 e_t + \beta_6 e_{t-12} + u^b_{t+12} \\ \begin{bmatrix} u^w_{t+12} \\ u^b_{t+12} \end{bmatrix} &= [\mathbf{u}_t] \sim MN\left(0, \mathbf{H}_{t+12}\right) \end{aligned} \tag{5}$$

where the series p^{wir} is the price of MCA adjusted Irish feed wheat, p^{wuk} is the price of British feed wheat, e is the sterling-punt exchange rate, p^{bir} is the price of MCA adjusted Irish feed barley, p^{buk} is the price of British feed barley, and the u^i are stochastic error terms. All variables are in logarithms. The conditional covariance matrix, **H**, is estimated following Baba et al. (1991) using the following model

$$\mathbf{H}_{t+12} = \mathbf{A}'\mathbf{A} + \mathbf{B}'\left(\mathbf{u}_t\, \mathbf{u}'_t\right)\mathbf{B} \tag{6}$$

In (6), **A** and **B** are 2x2 matrices. Equation (6) has the advantage that **H** is guaranteed to be positive definite. **A** is a lower triangular matrix and **B** is a full symmetric matrices. Under the assumption of conditional multivariate normality, the model can be estimated by

[6] There is a small but growing literature applying multivariate conditional first and second moment models to study international commodity price transmission simultaneously (see for

maximum likelihood or quasi-maximum likelihood methods. The model in equations (5)-(6) can be used to forecast means, variances and covariance of barley and wheat prices twelve months ahead.

In order to generate returns to cereal production one has to take into account prices, yields, costs and direct payments. The McSharry (1992) and the Agenda 2000 (1999) reforms of the CAP saw a philosophical change in the nature of EU income support for producers – guaranteed prices were to be gradually replaced by the introduction and subsequent increase of direct payments. In the cereals sector, these direct payments have come to represent a considerable portion of producers' revenues and gross margins. Table 1 summarises the ratio of total cereal subsidies[7] to total farm gross margins[8] on a per hectare basis for specialist cereal producers[9] in Germany, France, the UK and Ireland for 2000. Ratios are provided for three different standard gross margin (SGMs) ranges. From the table, it is evident the significant contribution to producer margins constituted by these payments. Therefore, at the time of planting the producer's expected return per hectare (gross margin) on any cereal in twelve months time is given by

$$E_t\left(\frac{P_{t+12}Y_{t+12}+D_{t+12}-C_{t+12}}{C_{t+12}}\right) \tag{7}$$

where P is the price per tonne, Y is the yield (measured in tonnes per hectare), D is a direct or area aid payment for the period 1993-2002 (D is the proposed decoupled payment for 2003) and C is the variable cost per hectare. We assume that farmers expect the yield to be the average of the last three years ($Y_{t+12}=(Y_t+Y_{t-12}+Y_{t-24})/3$) and costs to be the same as the previous year ($C_{t+12}=C_t$). Our results are robust if we use actual yields and costs. The direct

example, Dawson et al. (2000); Haigh and Bryant (2001); Jumah and Kunst (2001)).

[7] Set Aside and Arable Aid payments.

[8] Total farm revenues – total farm variable costs.

[9] Producers who have more than 66 per cent of their standard gross margins (SGMs) coming from cereal production.

aid and area aid payments, yield and variable cost data used in the generation of returns were obtained from both the Teagasc conducted National Farm Survey (NFS)[10] and the Teagasc Management Data for Farm Planning.

4. Results and Analysis

In order to generate expected efficient frontiers facing producers at the time of planting, we estimate (5)-(6) using data up to September of a particular year and then forecast the Irish barley and wheat prices, their conditional variances and the conditional covariance for the following September. Then, we add one year's data and repeat the forecasting exercise. This produces eleven September forecasts over 1993-2003 for the five conditional moments. We generate expected returns to cereal production using the expected prices, yields, direct or decoupled payments and variable costs per hectare using (7). The expected returns and risk are used to calculate the expected efficient frontier facing a producer in the year ahead. Analysis is simplified somewhat by the fact that wheat has always had the highest expected return and risk in all of the years 1993-2003. Thus, all efficient frontiers will look something like that depicted in Figures 1 or 2. We are now in a position to answer the first question we posed in the introduction, have specialist producers of Irish cereals been allocating land efficiently in a mean-variance sense over the period 1993-2002?

Using equation (3) we can calculate the weight attached to wheat at the minimum risk point on the efficient frontier, i.e. point M in Figure 1, for the years 1993-2002. These are presented in Table 2. In the years 1995, 1999 and 2000 the estimated weights attached to wheat at the minimum risk point on the efficient frontier were negative, which we rule out. Therefore in these years the least risky allocation would have been to produce only barley and the expected efficient frontier was estimated to be like B^*W in Figure 1. In these years,

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[10] See Heavey et al. (1997) for more details.

any allocation of land to barley or wheat production would have been *ex ante* mean-variance efficient. In the other years, the expected minimum variance frontier was estimated to be like BMW in Figure 1 and thus, the expected efficient frontier was MW. In these years only some of the optimal allocations of land to barley and wheat production were *ex ante* efficient, for example in 1993 specialist producers should have allocated at least 43.3% of farmland to wheat production to be on the efficient frontier. In Table 2, we also report the actual percentage of land planted by specialist barley and wheat producers. Our results indicate that specialist grain producers were producing efficiently in a mean-variance sense in every year of the 1993-2002 period.

The second question we posed in the introduction is if decoupled payments and cross-compliance costs were introduced in 2003 how would this alter the risk-return opportunities facing specialist producers of Irish cereals? For the year 2003, we hypothesise the introduction of decoupled payments as per the MTR and examine the implications for the optimal crop portfolio. In accordance with DG-AGRI (2002), we assume that the decoupled payment is determined by taking the historical average of direct and area aid payments per farm between 1999 and 2002[11] and dividing it by the total area on the farm to arrive at a per hectare payment. The figure arrived at is €387 per hectare.[12] This value is now used for D in calculating the return using equation (7) and to calculate the expected minimum variance frontier for 2003 as we did for the years 1992-2002. However, if decoupled payments are introduced in 2003, then the efficient frontier becomes a straight line depicted by either COL_1 or COL_2 in Figure 2 and not BMW.

We also need to calculate the risk-free rate of return in order to determine the expected optimal crop portfolio allocation at point O or P in Figure 2. Therefore, we need to make

[11] Note that DG-AGRI (2002) does not specify a specific time-period for the determination of historical payments. It merely states that the payments would be determined on the basis of the historical receipts of direct payments for the individual producer.

some assumptions about the cost of cross-compliance. We assume that participation in production would satisfy cross-compliance regulations. To date the EU Commission has given no indication as to the likely cost of this measure. However, we use two hypothetical values, €215 and €292 per hectare. The lower the cost of compliance, the higher the risk-free rate of return and the more likely farmers will switch to the relatively higher returning and riskier crop (wheat in the Irish case). If the cost of cross-compliance were €215 per hectare and the decoupled payments were €387 per hectare, the expected optimal crop portfolio in 2003 would require a 100% of land allocated to wheat production, i.e. the tangency point would be at W in Figure 2. On the other hand, if the cost of cross-compliance were €292 per hectare and the decoupled payments were €387 per hectare, the expected optimal crop portfolio in 2003 would require a 53% of land allocated to wheat production, i.e. the tangency point would be at a point such as O or P in Figure 2. It is evident from Table 2 that this is typical of the amount of land allocated to wheat by specialist producers between 1993 and 2002. Thus, if policymakers want to introduce decoupled payments but do not want to alter the allocation of land to barley and wheat production, we estimate, that the decoupled payment should be 32% higher than the cost of cross-compliance.

5. Conclusions

This paper, using portfolio theory, has estimated the expected efficient frontier confronting specialist Irish wheat and barley producers between 1993 and 2002. The expected returns and variances used in the calculation of the efficient frontier were obtained using a MVARCH model of Irish cereal prices developed by Roche and McQuinn (2002). Analysis of the expected efficient frontiers confronting Irish cereal producers and their actual

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[12] £305 in Irish currency.

land allocation decision suggests that they planted efficiently, in a mean-variance sense, in every year between 1993-2002.

Building on research by Blank (2001), the model was then expanded to examine the potential implications for the optimal planting decision in the presence of ‘decoupled’ payments in the arable sector as proposed in the MTR of the CAP. These decoupled payments less the cost of cross-compliance can be regarded as being equivalent to a risk-free return. We estimate that if the decoupled payment were set to be about 132% of the cost of cross-compliance the optimal crop portfolio would result in 53% of land being allocated to wheat production. This is the typical percentage of land allocated to wheat production in Ireland. We also estimate that if the decoupled payment were set to more than 180% of the cost of cross-compliance the optimal crop portfolio would result in 100% of land being allocated to wheat production.

Much work is already underway in the examination of the potential production effects of decoupling agricultural support payments, the OECD for example is “working on developing a broad concept of decoupling and a body of empirical studies that could underpin this concept” (see Anton (2002)). It is hoped that the approach presented here, while relatively straightforward, would serve as a useful complement to this general investigation.

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Figure 1
The efficient and minimum variance frontiers facing barley and wheat producers

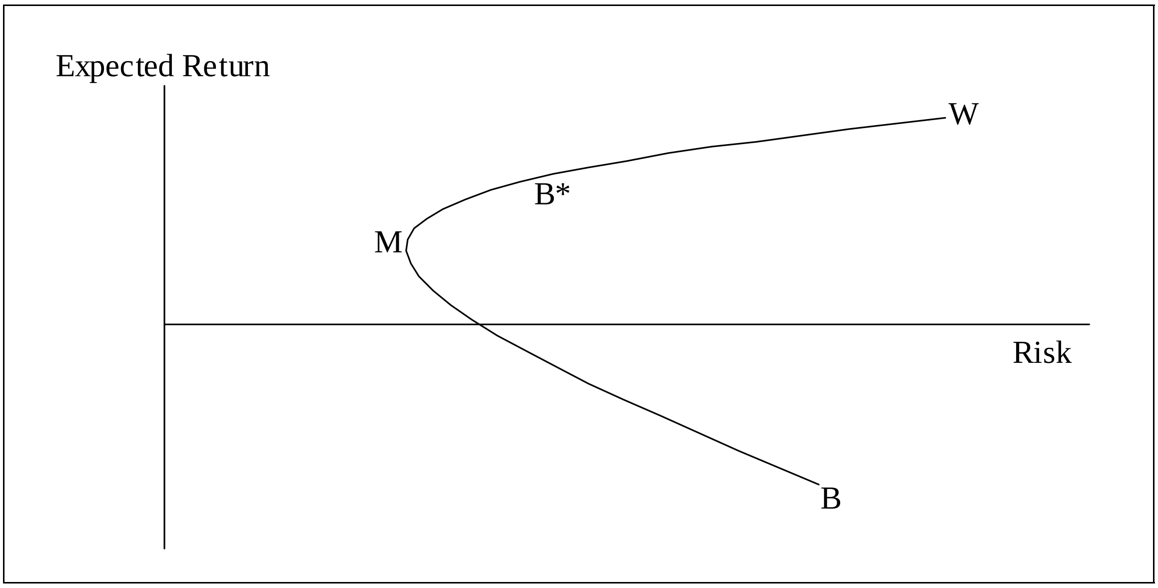

Figure 2
The cropping opportunities line facing barley and wheat producers

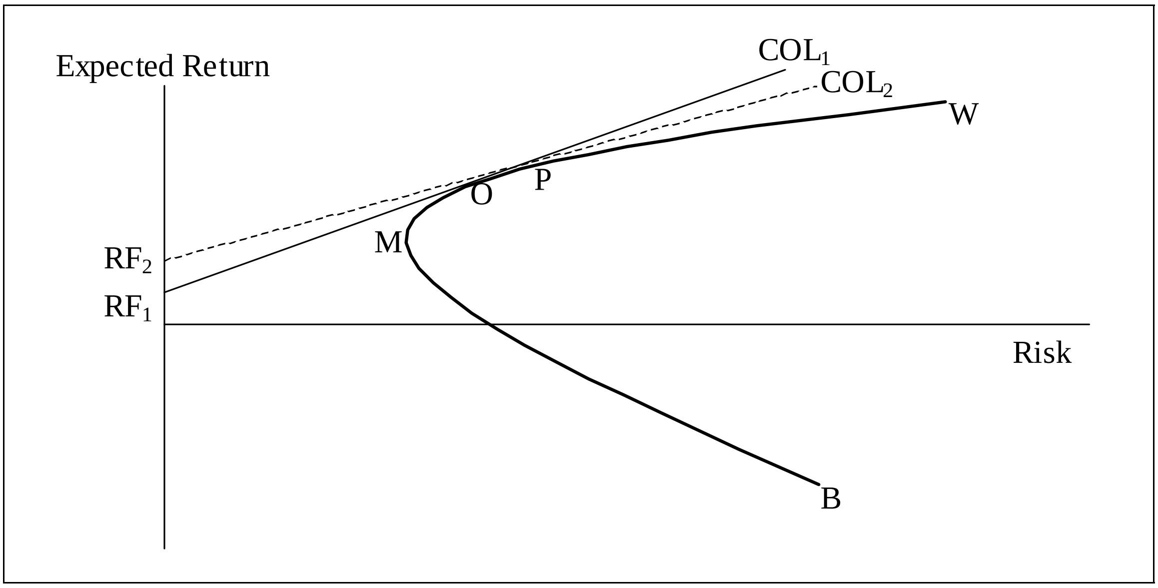

Figure 3
Irish and British feed wheat prices in pounds sterling

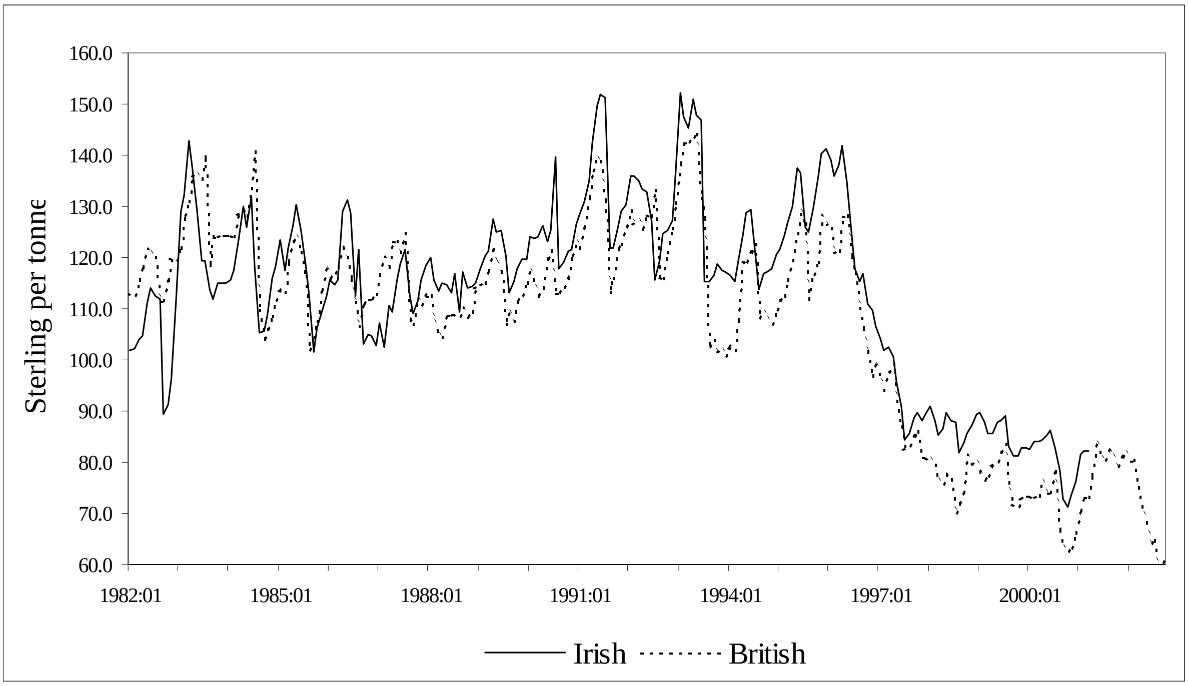

Figure 4
Irish and British feed barley prices in pounds sterling

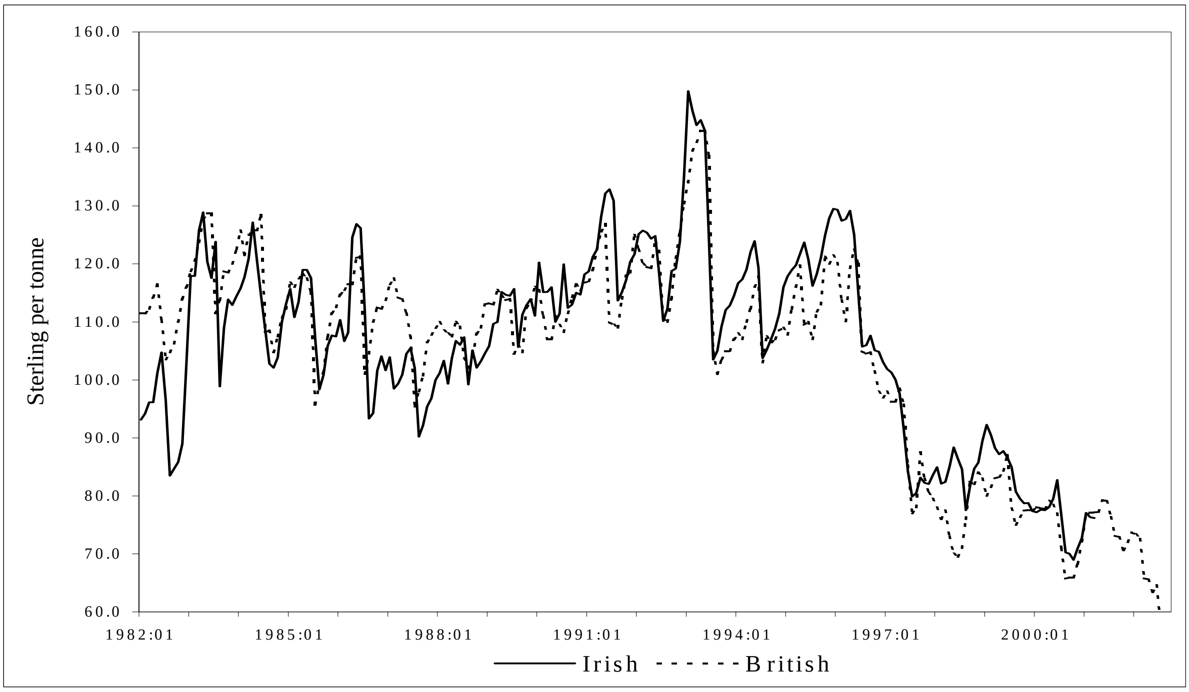

Table 1
Ratio of crop subsidies to total gross margin per hectare

SGM €	Germany	France	UK	Ireland
19,200-48,000	77	79	89	63
48,000-120,000	79	72	86	56
> 120,000	64	65	68	57

Source: Farm Area Data Network (Eurostat) and the Irish National Farm Survey (Teagasc).

Table 2
The minimum variance and actual combinations of wheat and barley

	Percentage attached to wheat at minimum variance crop portfolio	Actual percentage of farmland allocated to wheat production
1993	43.30%	51.18%
1994	12.94%	53.00%
1995	-14.86%	53.16%
1996	13.01%	52.74%
1997	18.09%	52.59%
1998	25.95%	58.78%
1999	-21.14%	53.58%
2000	-35.16%	54.35%
2001	32.81%	NA
2002	20.99%	NA

Note: The actual percentage of farmland allocated to wheat production is for specialist producers of Irish cereals. NA is not available.