Modelling Farmer Response to Policy Reform: An Irish Example

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Abstract

This paper presents the results of a study in which multi-period linear programming models are used to project the likely impact of EU agricultural policy reform on dairy and cattle farms in Ireland. Representative farms are selected from the Irish National Farm Survey using cluster analysis. A Markov Chain analysis is conducted to estimate the future representivity of farming clusters. Models are validated historically and calibrated according to farmers' historical tendency to achieve 'optimal' outcomes. Price and cost projections are taken from an econometric model of Irish agriculture and used in the programming models to demonstrate the effect of policy on farm plans and resulting farm profit.

Keywords: representative farm, multi-period linear programming, Markov Chain analysis

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1: Introduction

The work described in this paper has been developed under the auspices of the FAPRI-Ireland Partnership. The FAPRI-Ireland Partnership was established to conduct analysis of policies that impact on the Irish agricultural sector. The Partnership involves collaboration between Teagasc (The Irish Food and Agriculture Development Authority), several Irish universities and FAPRI (Food and Agricultural Policy Research Institute) in University of Missouri. The analysis procedure typically begins at the macro level with an econometric model of Irish agriculture. Following simulation at the macro level, the projected agricultural costs and prices link into a farm level linear programming model.

This paper focuses on the farm level stage of the analysis. There is a brief discussion of the modelling of policy change at the aggregate level followed by a more in-depth explanation of the farm level models. The methodology and data applied is discussed in detail in the ensuing text. This is followed by a shorter discussion of some results of policy analysis conducted using these models.

2: Methodology

The complexity of agricultural policy necessitates the use of different modelling methodologies. Some policy changes are aggregate in nature only, for example a reduction in export subsidies and can be modelled using aggregate models only. However, other policy changes may mostly take effect at the micro level, for example a change in direct income support in the form of livestock subsidies or farm specific subsidy modulation. Farm level models are required for the analysis of such policies. Furthermore, farm level models are also informative on the impact of aggregate policy changes. While the aggregate model will show the effect of a policy on commodity markets and prices, the farm level model will show the distributional implications of new policy, i.e. which type of farms are worse affected etc. Hence, two modelling approaches are used and each approach informs the other. This allows a more comprehensive analysis of the impacts of policy change than if a single approach was used.

2.1: Econometric Model of Irish Agriculture

The macro model is comprised of a set of individually estimated commodity models, e.g. beef, dairy, sheep, pigs and cereals that are linked and solved simultaneously under different policy scenarios. The commodity models developed by Binfield et al (2002) are standard recursive dynamic partial equilibrium models. The individual commodity models for Ireland are linked to the EU and World models of agriculture maintained by FAPRI in the USA (Westhoff 2002). Small country assumptions are invoked for the case of Ireland and therefore prices are estimated as a function of the prices emanating from the EU model.

2.2: Farm Level Models

A set of multi-period linear programming models for Irish representative farms is used to estimate the effect of a policy change in Ireland. Price and cost projections from the commodity models link into the LP models and farm profit is optimised over a ten year period for eight representative farms.

Representative Farms

Irish National Farm Survey (NFS) data is used for the farm level models. The NFS surveys 1,200 farms annually and these are weighted to represent the total farming population of approximately 120,000 farms. Rather than modelling all 1,200 farms, a representative farm approach is used.

The representative farm approach involves clustering all 1,200 farms into a number of strata, so that farms within each stratum are relatively homogeneous and each stratum is significantly heterogeneous from the other. Within each stratum, the representative farm is selected, that is the farm that is deemed to be representative of all farms in the stratum. The farms are called representative rather than typical as farm types used may also be atypical but may be representative of a small minority, Klein (1981). Representative farms have long been used as the basis for describing the behaviour of the total farming population, Plaxico and Tweeten (1963) and Sharples (1969).

There have been numerous studies on the correct procedure for classifying representative farms. All studies point towards the importance of classifying farms into homogenous groups. Day (1963) laid the foundations for this classification procedure. His foremost criterion for classification was - *technological homogeneity.* He defines this as similar resource endowments and constraints, similar levels of efficiency and similar managerial abilities. Other classification criteria have been identified since Day's. Buckwell and Hazell (1972) emphasised the importance of groups having similar expectations of changes in constraints and similar rates of technical innovation.

Cluster and principal component analysis is carried out based on these classification procedures. Variables chosen from the NFS, act as proxies for the classification criteria. The variables used are three-year averages from 1996 to 2000. The motivation for this is to minimise the disturbance of inter-year variations on farms due to exogenous factors such as weather, price volatility etc. To enable historical validation and calibration at a later stage, it is necessary to construct a panel of matched data from the farm survey. The required data is drawn from a balanced panel from 1992 to 1996. To ensure the unbiasedness of the panel, a t-test was conducted to test the significant difference between the panel population and total population. Tests were carried out along five variables. The results showed that although the panel tended to contain slightly larger and more profitable farms the differences were not significant.

The results of the cluster analysis for dairy and cattle farms are tabulated below. The tables show the main descriptors for the farms in each cluster. The number of farms represented nationally is shown in parentheses for each cluster. The clusters have been named according to their most discriminatory characteristics.

Table 1: Description of Representative Dairy Farms

Farm Types (Percentage of pop)	Medium (37%)	Developers (20%)	Transitionary (22%)	Large (21%)
Quota Size – gallons	40,000	30,000	20,000	88,000
Land Area – hectares	46	35	25	80
Yield per Cow – gallons	1100	1000	1000	1150
Change in quota 1996 – 2000	+15%	+20%	-5%	+5%

Source: Derived from Irish National Farm Survey

The figures presented in Table 1 are average values for the representative dairy farms, clearly there are deviations around these means. For example, in the transitionary group the average quota size is 20,000 gallons but farms in this group have quotas ranging from 2,000 gallons up to almost 35,000 gallons. The developer and transitionary groups are not significantly different from each other in terms of quota, land size and even efficiency per cow. However, they do differ substantially on their historical growth records. Change in quota farmed was one of the key variables used for segregating these two groups. The developer group has expanded quota farmed by on average 20 per cent in the period of 1996 to 2000 while the transitionary group have on average reduced quota farmed.

Table 2: Representative Cattle Farms

	Off-Farm Employment		No Off-Farm Employment	
Farm Types	**Hobby (25%)**	**Efficient (20%)**	**Large (18%)**	**Small (37%)**
Utilised Agri. Area (hectares)	20	27	52	25
Gross Margin per Labour Unit €	9,000	23,000	35,500	12,000
Age	50	45	52	65
Stocking rate lus per hectare	1.4	1.8	2.1	1.3

The population of 62,500 specialist cattle farms is presented as four representative farms in Table 2. On 45 per cent of specialist cattle farms the farmer has some employment off farm. Within the group of 'part-time' farms, two very different clusters emerge, the hobby group and the efficient group. Although both part-time farms are similar in size, they are significantly different in level of activity, efficiency and profitability. The hobby farmer derives a significantly lower level of profitability per labour unit in comparison to the efficient farmer. It is important to segregate these two farm types, as they are likely to respond differently to changing prices, costs and policies. Those without off farm employment are easily differentiated, they differ in size, efficiency and profitability. The demographics of these farms are also very different. The average age of the large farm operator is 52 in contrast to the small cattle farmer with an average age of 65.

Linear Programming Models

A linear programming model of each representative farm is maintained. Linear Programming is a subset of Mathematical Programming. From an analytical perspective, a mathematical programme tries to identify an extreme, i.e. minimum or maximum point, of a function $f\ (x_1, x_2, \ldots x_n)$, which furthermore satisfies a set of constraints, e.g., $g(x_1, x_2, \ldots x_n) \leq b$. Linear programming is the specialisation of mathematical programming where both the function f, the objective function and the problem constraints are linear.

The general form of a linear programming model can be expressed as,

$$\text{Max/Min } f\ (x_1, x_2, \ldots x_n): = c_1\ x_1 + c_2\ x_2 \ldots c_n x_n \qquad (1)$$

subject to,

$$a_{i1}\ x_1 + a_{i2}\ x_2 + \ldots + a_{in}\ x_n\ (\leq \text{ or } \geq)\ b_i, \quad \text{for all } i \qquad (2)$$

$$x_j \geq 0, \text{ for all } j \qquad (3)$$

where x_n represents the level of activity n, c_n represents the return to activity n or cost of activity n, a_{in} represents the resource requirement per unit of activity n and b_i represents the resource constraint.

The representative farm models are profit maximising and multi-period. Farm net margin is maximised over a period of ten years. Projections of prices and costs for the ten year period are taken from the econometric model of agriculture. Farm specific data in the LP models are extracted from the Irish National Farm Survey.

The LP models are for the specific purpose of policy analysis. Farmers' response to a change in agricultural policy is simulated based on the assumption of profit maximisation and the resulting effects on farm income are estimated. The LP model is a useful tool for policy analysis at the farm level because it can easily handle the sometimes complex and counterintuitive intricacies of European agricultural policy. To take for example the livestock extensification scheme, the extensification scheme rewards farmers for stocking fewer animals on a per hectare basis. Therefore, the farmer must calculate which is more profitable, reduce animal numbers and qualify for the reward or increase animal numbers and not apply for the scheme. Such a calculation can easily be handled in the linear programming framework.

As the models are for policy analysis, not all farmer decisions and production processes are modelled. As discussed by Hanf and Koester (1980), when seeking an answer to a specific question it is sometimes necessary to reduce model size by using a more aggregate consideration of some parts of the farm, where as other aspects under consideration may be more disaggregated. As the specific question under examination is the impact of policy, the models are highly specified on policy issues and less so on the specification of production processes. The scope of the models is confined to the analysis of resource allocation decisions, in particular land and labour, enterprise mix and volume of production decisions, participation in policy schemes and the resulting impact of these decisions on income. The model does not attempt to analyse production process decisions and so some simplifying assumptions are invoked in the specification of the model.

Technical coefficients are as recorded by the National Farm Survey for the representative farm and they are assumed to be fixed, in other words for a given process of production only one combination of factors of production is possible. Clearly, there are a number of alternative production processes, each requiring a different combination of factors of production and producing different levels of output, however just one production process is modelled. Hence, the models are not specified to analyse the profitability of a low-cost, low output system versus a high-cost intensive system, nor can the models examine the profitability of input substitution.

Validation and Calibration of the Linear Programming Model

There are four years of historical data available for each representative farm and this enables backward projection and historical validation. With the availability of historical data it is possible to test the goodness of fit between the behaviour of the historical model and the observed data. To do this, the LP model is adapted to represent the earliest year for which data is available. The historical model is then used to project farm income for the next four years. The projected income and farm plan are then compared to the actual to test the performance of the model. This procedure usually highlights some issues in the model that need to be debugged and some constraints that need to be re-specified.

Despite continued improvements in the specification, the projected outcomes do not always completely fit the actual, although for some of the 'commercial more efficient' representative farms, especially the large dairy and cattle farms, the projections usually fit quite well. There are many reasons why the optimal may differ from the actual even when the model is well specified. Flemming (1998) identified farmer-specific issues such as aversion to risk and lack of education as reasons why farmers may not be willing or able to reach optimal profit. Many of these issues can be quantified in the model by adjusting the objective function. However, when profit maximisation is assumed, as it is here, there will be a continued discrepancy between the model's projected behaviour and the observed behaviour.

The difference between the projected optimal and the actual outcome can be measured historically. This inability to reach the profit maximisation optimal is termed the 'response deficit factor'. With historical data on the response deficit factor is projected forward to estimate future deficit factors. Future optimal outcomes are calibrated and adjusted downwards by the response deficit factor where appropriate. The response deficit factor operates as a performance correction tool and enhances the positivity of the results. The amount by which results needed to be calibrated downwards varied by representative farm and by policy scenario.

Structural Change in Representative Clusters

The representative farms are defined as representing a certain number of farms in the year they were selected. However, the representivity of clusters may change over time. A Markov Chain model is a useful technique for analysing such change. A first order Markov Chain model was developed to model the changing representivity of the farms.

A Markov Chain is a series of mutually exclusive and exhaustive states with a given population at each point in time, accompanied with probabilities of transition for each observation from one state to another. In the First Order Chain, the probability of transition from one state to another at a given point in time is equal to the probability of transition in the previous period. Hence, the probabilities of transition do not change with time or with changing exogenous forces and are therefore stationary. Previous such studies carried out on the Irish farm structure have proved quite accurate, for example Keane (1991).

If the Markov Chain is a first order stationary one, then each transition probability in the matrix can be calculates as follows;

$$\boldsymbol{P}_{13}(t) = \boldsymbol{P}_{13}(t-1). \qquad (4)$$

In other words, the probability of farms moving from structural state 1 to structural state 3 is equal to the movement of farms between these states in the previous period.

In this analysis, the population of representative farms in 1996 was estimated and then again in 2000. The rate of transition was estimated and then used to project the population for 2004. Results showed an increase in the population of large and transitionary dairy farms with a decline in the medium and developer representative farms. This seems seems to indicate that farms are either becoming small exiting units or are becoming larger to take advantage of economies of scale. Such polarisation is typical of the agricultural structure of developed countries, (Sandrey and Reynolds

1990). For the cattle farms the population of the part-time farming group and the commercial full-time group is projected to increase.

3: Results

The FAPRI-Ireland Partnership produces annual ten-year projections under a 'baseline' assumption. A baseline assumes no new policy changes, that is, projections show what prices would prevail if current policies continued unchanged. While the baseline may seem to be based on an unrealistic assumption, it is a useful concept as it acts as a yardstick to measure the effect of other policy scenarios.

In 2002, the FAPRI-Ireland Partnership produced a ten-year baseline projection and conducted analysis on the potential effect of a change in the extensification[1] scheme. The results of these analyses are discussed here. A brief discussion of the results at the aggregate level is provided, and a more in-depth explanation of the results at the farm level is presented.

Aggregate Projections

The baseline projections produced by the aggregate model (Binfield et al 2002) shows that in general, commodity prices are due to increase but much of this increase is eroded by the appreciating euro relative to the dollar. Cattle values are projected to decrease by 10 per cent while the output value of the dairy sector is expected to decrease by 7 per cent due to the increase in the EU milk quota. However, subsidies on products and production are projected to increase throughout the projection period. The net effect is that by 2010, total income of the agricultural sector is projected to be 3 per cent above the 2000 levels in nominal terms.

The impact of a change in the extensification scheme was also considered. The models were used to project the effect of a stricter but more financially attractive extensification scheme[2]. It was hypothesised that the EU Commission may use the extensification scheme to discourage the production by beef by increasing the reward to farmers who lowered their stocking rate even further than the current extensification rate. The key findings of this analysis at the aggregate level was that the Irish suckler cow herd would decline by 3 per cent, the volume of beef output would decline by 1.5 per cent and the reduction in production would result in an increase in the Irish cattle reference price by 5 per cent.

[1] The extensification scheme is a direct income support scheme through which farmers receive annual livestock payments on steers and suckler cows if they maintain their stocking rates below a certain level.

[2] In Ireland under the Agenda 2000 Agreement extensification payments per animal are paid at the rate of € 40 per animal on farms stocked at between 1.8 and 1.4 L.U. per hectare, and at a rate of € 80 per animal on farms stocked at less than 1.4 L.U. per hectare. Under the scenario these 2 limits are both reduced by 0.2 L.U. per hectare. Thus, the under the scenario the extensification limits are 1.6 to 1.4 L.U. per hectare, and less than 1.2 L.U. per hectare.

Farm Level Projections

The farm level models were used to show the effect of the baseline and policy scenario projections on all eight representative farms. Baseline projections showed rising direct and overhead costs erode margins on all farms. Farmers who do not expand production or improve efficiency will be subjected to a price cost squeeze and incomes could fall by as much as 20 per cent in nominal terms.

Transitionary dairy farmers are projected to exit the industry by 2005, while small developing and medium sized farms are expected to expand quotas owned by up to 20 per cent. Income on large farms will fall by approximately 25 per cent unless milk production is increased or productivity and cost management is improved, however without the exit of more farms there will not be sufficient quota for farmers to expand their businesses. Incomes on cattle farms are projected to be relatively higher from 2002 to 2005, as cattle prices and direct payments increase in value. From 2005 onwards, cattle farm incomes are projected to fall due to lower prices, fixed value of direct payments and rising costs. On large cattle farms, incomes are projected to fall by over 10 per cent in nominal terms over the next ten years. The new 1.8 livestock unit ceiling, which is imposed on stocking rates from 2003 onwards, is a significant contributor to this decrease.

Under the policy scenario margins are higher on all farms due to increased beef prices. The small full-time and part-time efficient cattle farms reduce stocking rates to avail of the higher extensification payments. The other farms do not change their stocking rates but nevertheless benefit from the higher prices for beef.

Results of Policy Analysis

The analysis of the extensification policy scenario was conducted at the aggregate and farm level. The results showed that the scenario was effective in achieving its goal of reducing beef supply despite increased prices, albeit only marginally, supply in Ireland fell by almost 2 per cent. It also showed that the policy scenario would result in all farmers being better off under this new scenario. However, the budgetary implications of such a policy were not investigated.

As this policy scenario is, for the most part, a micro-level policy, that is it takes effect at the farm level, the normal procedure for policy analysis with these models was changed somewhat. The policy scenario was first analysed with the farm level models. The participation rate by farmers in the new extensification schemes was estimated and this information was used in the aggregate beef model to estimate supply response, from this newly estimated supply response, price projections were produced. These price projections were linked to the farm level models and the participation rates were re-estimated. This process was continued until equilibrium was reached.

4: Conclusions

The FAPRI Ireland Partnership has been highly successful in the analysis of agricultural policies. The Partnership has been involved in the analysis of a number of policy proposals at the request of the Irish Minister for Agriculture and the models' output has been used in policy negotiations in Brussels to secure the most beneficial policies for Ireland. The models are in a continual state of development and new policy proposals can often necessitate some further model development or re-specification.

This paper describes the modelling process, which estimates the effects of a policy change at both macro and micro levels. At the micro level, which is the focus of this paper, the effects of price and cost projections under the baseline and a policy scenario on different types of Irish farms are analysed and the likely farmer response is projected. The results presented here should be regarded as an illustrative example of the comprehensive output produced by the models which extends from sector income to the effect of policy on different types of farms.

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