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# Developing the Spatial Dimension of Farm Business Models

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## Abstract

*A non-linear mathematical farm business optimisation model, that is set within a spatial economic framework, has been developed. The model incorporates factors such as location, spatial market orientation and technology use, and identifies the business strategy that is optimal in different market and policy environments. Farm household time-use is incorporated centrally within the model, enabling it to examine how on-farm and off-farm activities compete for limited farm household human resources. The model is applied to a beef and sheep farm that can choose between selling livestock to meat processors or processing on-farm and selling direct to consumers. Model simulations reveal when it is optimal for the farm business to innovate in this way and how this decision is affected by changes in key parameters. The farm business model is solved using the GAMS/LINDOGlobal mathematical programming software package. While traditional nonlinear programming and mixed-integer nonlinear programming algorithms are guaranteed to converge only under certain convexity assumptions, GAMS/LINDOGlobal finds guaranteed globally optimal solutions to general nonlinear problems. The model and model results are discussed within the context of theoretical underpinnings, model tractability, and potential applications*.

## 1. Introduction

The spatial dimension has been incorporated into many areas of economic analysis, for example, trade (Takayama and Judge, 1964a and 1964b), imperfect competition (Greenhut et al., 1987), business management (Kallrath and Wilson, 1997), computable general equilibrium (Kilkenny, 1999), and agent-based modelling (Happe et al., 2006). The introduction of spatial factors can sometimes greatly improve our understanding of the behavior of economic agents and markets. For example, see Brennan et al. (1997) concerning the motivation for holding wheat stocks, and Suri (2011) regarding agricultural technology adoption. Kilkenny and Otto (1994) assert the premise that space, as a benefit (environmental amenity), as a cost (distance from markets), and as the location of unique physical, demographic, and economic features of regions, is a key determinant of rural development. This paper investigates the modelling of optimal business development strategies for farm businesses within the specific context of their spatial economic environment.

There are various aspects of the local business environment that are likely to influence the optimal development strategies of farm businesses. These include the cost and availability of suitable land, the nature of local input and product markets, the condition of local transport and communications infrastructure, and the consequences of being in close proximity to the natural environment. The characteristics of these factors are not only determined by the prevailing market conditions but also by the type, level and implementation of public policy. Natural resource based firms such as farm businesses are almost always to be found in a rural location, therefore, their chosen business strategy results from a need to adapt to this rural location. From a theoretical perspective, it is recognized that modern economic geography models (i.e. new economic geography) have rudimentary business strategy foundations.

A non-linear mathematical business optimisation model, that is set within a spatial economic framework, was developed. The model incorporates important areas of business strategy, such as, spatial market orientation and technology use. It identifies the business strategy that is optimal in different market and policy environments. The model is applied to a beef and sheep farm that has the opportunity to choose between selling livestock to meat processors versus processing on-farm and selling direct to consumers. The model incorporates activities relating to cattle rearing, sheep rearing, meat processing, meat marketing, transportation, land, labour, working capital, capital expenditure, and public policy. The technical coefficients for the model were calibrated using data contained in farm management and research publications. Consultation with industry experts enabled these coefficients to be further validated. Model solution identifies the income maximising business strategy for that farm, given the initial set of farm resources and market conditions assumed. Model simulations reveal when it is optimal for the farm business to innovate and how this decision is affected by changes in key parameters. The paper discusses the model, and the model results, within the context of theoretical underpinnings, model tractability, and potential applications.

Farm household time-use is incorporated centrally within the model, enabling it to examine how on-farm and off-farm activities compete for available farm household labour. The model specifically includes farm work, off-farm employment, leisure, care (children or adult) and home production[1]. Options for hiring in labour resources are also present in the model. Model options exist to enable the renting in, or renting out, of various types of land. Moreover, options exist to allow the borrowing of working capital within maximum borrowing limits. In addition the option of investing the business's own working capital off-farm is also available. For each of the resources leased in or purchased, the supply functions faced by the business are assumed to be either constant or upward sloping. Similarly, for each of the resources leased out, invested or employed off-farm, the demand functions faced by the business are assumed to be either constant or downward sloping. The model also incorporates average variable and fixed costs of processing, transportation and marketing meat products which relate to all processing, transportation and marketing costs except labour and raw material (i.e. beef and lamb) costs. These average variable and fixed costs of processing, transportation and marketing of meat products are assumed to be

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[1] Home production includes activities such as cooking, cleaning, laundry, gardening, household shopping, and routine maintenance)

output dependant. Finally, the farm business is assumed to face downward sloping consumer demand functions for processed and marketed beef and lamb products.

The farm business model is solved using the GAMS/LINDOGlobal mathematical programming software package. GAMS (General Algebraic Modeling System) is a matrix generator that was originally developed to assist economists at the World Bank in the quantitative analysis of economic policy questions. It allows modellers to generate many of the model parameters automatically, which enables model simulations to be conducted quickly and accurately. Optimization models created with GAMS must be solved with a programming algorithm(s), and GAMS/LINDOGlobal was used in this case. While traditional nonlinear programming (NLP) and mixed-integer nonlinear programming (MINLP) algorithms are guaranteed to converge only under certain convexity assumptions, GAMS/LINDOGlobal finds guaranteed globally optimal solutions to general nonlinear problems with continuous and/or discrete variables. The LINDO global optimization procedure employs branch-and-cut methods to break an NLP model down into a list of sub-problems. Given appropriate tolerances, after a finite, though possibly large number of steps, a solution that is provably global optimal is found (Brooke et al., 1998; and GAMS Development Corporation, 2010).

## 2. Policy Issues

Innovation in rural areas requires greater attention from all levels of government, including the devolved administrations. Rural innovation is often either overlooked in regional innovation strategies, or only scantly mentioned in very specific contexts (such as Foot and Mouth Disease, or broadband projects). Central Government also tends to neglect rural areas as locations for innovation, focusing instead on cities and their adjacent regions (Mahroum et al., 2007). The problems of rural innovation are often found to be more acute in remote rural areas. For example, Patterson and Anderson (2003) in a matched plant study found that remote rural manufacturing plants followed a production-cost oriented non-local market strategy while accessible rural firms adopted a more innovation-oriented non-local market strategy. Moreover, while the attractiveness of the rural environment contributes to the perception of a higher quality of life in the countryside, it may be difficult however for government policy simultaneously to encourage the expansion of business activity while at the same time trying to maintain an attractive rural environment. That remote rural firms have been found to be more likely to cite environmental regulations as a significant constraint on business growth is clear evidence of this tension (Anderson et al., 2004).

The costs of transportation and communication also affect the relative competitiveness of rural businesses. Rural businesses incur relatively higher transaction costs in both their input and product markets. Interestingly, Anderson, et al. (2005) found that rural businesses are shown to be more innovative than urban businesses in the area of supply and distribution, which suggests that rural businesses are more active in the adoption of innovations that help alleviate the problems associated with distance. It may be possible to alleviate some of the problems of being distant from input markets, product markets, business services, or social events through the use of modern information technologies.

Innovation in the rural economy can now be observed in the most traditional of land-based industries such as agriculture. Many farmers are attempting to re-integrate themselves into regional and local markets by marketing value-added food products on the basis of their geographical identity. This may involve a switch to specific niche markets by selling higher-quality products embedded with information about product, process and place. These market niches sometimes involve more value-added processing at the farm or local level and often mean more direct contact between farmers and consumers, which can help to stimulate product and process innovation (Atterton and Ward, 2007). After reviewing a number of recent studies and comments, MacLoad (2008) identifies a range of benefits that farmers' markets, for example, may provide to consumers and the wider community. These include: (1) allowing access to fresh and nutritious produce, (2) providing quality assurance and traceability, (3) supporting the local economy, (4) encouraging more environmentally friendly production and marketing systems, and (5) aiding community development.

## 3. Methodology

In order to identify optimal farming strategies for Hill Beef and Sheep farms within Northern Ireland the representative farm modelling approach was adopted. This involves firstly the identification of groups of farms within the population with similar important characteristics, and secondly the creation of a representative farm model for each group (Hazell and Norton, 1986). The representative farm models can then be solved under differing pricing and policy assumptions to identify the optimal farming system for each group of homogeneous farms. Previous research efforts where the representative farm modelling approach was employed include Thomson and Buckwell (1979), Wallace and Moss (2002), and Gomez-Limon and Riesgo (2004).

### 3.1. Developing a Representative LFA Beef and Sheep Farm Model

Data from a random sample of 200 farm businesses within the target population were obtained through the undertaking of a face-to-face survey. The multivariate techniques of factor and cluster analysis were employed to identify, firstly, the underlying constructs that characterise these farm businesses, and secondly, the groupings of relatively homogeneous farms in terms of land, labour and enterprise characteristics. Factor analysis found significant relationships between land quality and enterprise mix, and also between beef production activities and labour profile. Cluster analysis identified ten distinct groups of farms, but allocated the majority of farms to four large clusters of relatively small farms. These small farms not only accounted for a large percentage of this sector's businesses (85.5%), but also of the sector's beef cows (59.5%), other cattle (59.2%) and breeding ewes (44.3%).

The representative farm model and results presented in this paper relate to one of the ten distinct LFA beef and sheep farm clusters discussed above (i.e. cluster/model seven). The rationale for presenting simulations from representative farm cluster/model seven is because this cluster/model represents medium sized LFA beef and sheep farms. These farms may be of a sufficient scale in terms of land, labour and working capital to successfully diversify into direct sales of their beef and lamb to consumers. Within this cluster, 92% of farms have beef cows with herds ranging between thirty and eighty-four cows, all farms have other cattle with numbers varying between forty-four and two hundred and thirty-five head and 46% of the farms have breeding ewes with flocks between twenty and two-hundred and eighty-five head.

Physical and financial assumptions of the different farming options incorporated within the model are based on information from farm data books, research publications, market reports, and communication with industry experts. The levels of owned farm resources assumed within the each representative farm model are based upon data obtained from the LFA beef and sheep survey undertaken. The model incorporates activities relating to cattle rearing, sheep rearing, livestock marketing, meat processing, meat marketing, land, labour, working capital, capital expenditure, and public policy. Upon solution each farm model selects the levels of these different options that formulate an overall profit maximising farm business strategy.

### 3.2 Cattle Rearing Activities

The models currently contain five beef cow options. The first option is a spring calving continental (i.e. Limousin cross Friesian) beef cow that is crossed with a charolais bull and housed during the winter period. The second option is an autumn calving continental (i.e. Limousin cross Friesian) beef cow that is crossed with a charolais bull and housed during the winter period. The third option is a spring calving traditional (i.e. Angus cross Friesian) beef cow that is crossed with an Angus sire and housed during the winter period. The fourth option is an autumn calving traditional (i.e. Angus cross Friesian) beef cow that is crossed with an Angus sire and housed during the winter period. The fifth option is a spring calving traditional (i.e. Angus cross Friesian) beef cow crossed with an Angus sire but in this instance winter management is outdoors. For these beef cow options an average calving date of 1st March for spring calving cows and 1st September for autumn calving cows are assumed.

Within the models there are four options relating to the rearing of replacement heifers. The first option is the rearing of spring calving continental type (i.e. Limousin cross) replacement heifers, the second option is the rearing of autumn calving continental type (i.e. Limousin cross) replacement heifers, the third option is the rearing of spring calving traditional type (i.e. Angus cross) replacement heifers and the fourth option is the rearing of autumn calving traditional type (i.e. Angus cross) replacement heifers. It is assumed under all options that replacement heifers are sourced from the dairy herd, housed during the winter period, and calve at 24 months.

Within the models options exist for the finishing of suckled calves produced by the various beef cow options. The finishing options are steers at 22, 23, and 24 months, and heifers at 19, 20, and 21 months. Housing in the winter period only is assumed for all the steer and heifer options.

The combination of beef cow and calf finishing options incorporated within the model enables the farm, if required, to supply standard beef (continental bred) and Aberdeen Angus branded beef in all 52 weeks of the year.

### 3.3 Sheep Rearing Options

Within the models there are four breeding sheep options. The first option relates to a Scottish Blackface ewe that is bred pure with a Scottish Blackface ram and lambs in April. The second option is a Scottish Blackface ewe crossed with a Texel ram that lambs in April. The third option is a crossbred ewe crossed with a Texel ram and again lambing in April. The fourth option is a crossbred ewe crossed with a Suffolk ram and lambing in January. It is assumed that Scottish Blackface ewes are out wintered and Crossbred ewes are housed. It is also assumed that for each breeding ewe option that any store lambs produced are weaned on the 1st September.

Within the models there are three options relating to the rearing of replacement ewe lambs. The first option is the rearing of home produced Scottish Blackface lambs that are assumed 16 kilograms halve weight. The second option is the rearing of purchased Scottish Blackface ewe lambs, which are assumed 14 kilograms halve weight. The third option is the rearing of crossbred ewe lambs. It is assumed that both Scottish Blackface ewe lamb options involve out-wintering, whereas the crossbred ewe lamb options involve housing. It is also assumed that crossbred ewe lambs are bred as ewe lambs, whereas Scottish Blackface ewe lambs are first bred as hogget's.

There are different options for the finishing of store lambs produced by the various breeding ewe systems. The first set of options relate to the finishing of store lambs indoors. It is assumed that lambs are initially grazed from the 1st September and then housed and fed concentrates ad-lib from the 1st November. The second set of options involves the finishing of lambs on grass supplemented with concentrates, with lambs entering these systems on the 1st September. The third set of options relate to the finishing of store lambs on grass alone, with lambs again entering these systems on the 1st September.

The combination of breeding ewe and lamb finishing options incorporated within the models enables the farm, if required, to supply standard (crossbred) lamb in all 52 weeks of the year. The model also enables the farm to produce Scottish Blackface branded lamb in the months of October, November, December, January, February, March and April.

### 3.4 Livestock Selling & Buying Options

Each model has options that allow the sale of finished cattle, finished lambs, suckled calves, store lambs, cull cows, cull bulls, cull ewes, and cull rams. Net revenue values for each type of finished prime cattle are calculated on model solution on the basis of assumed deadweight, beef price, and slaughter deductions. The assumed beef price for each animal is calculated from a reference base price (i.e. the average annual U3 steer beef price), by taking into consideration price seasonality, grade bonuses/penalties, and market bonuses. In all models Farm Quality Assured Status is assumed and therefore Farm Quality Assured prices are applied. The seasonal beef price variations within the models are based upon monthly U3 beef price variations that occurred over the period 2002-2005. The average observed deviations from U3 steer price for the different possible grades of steers and heifers during the years 2004 and 2005 are also used within the models to make the appropriate grading adjustment when calculating a beef price for each animal from the annual average U3 steer price assumed. Price bonuses for marketed Aberdeen Angus steers and heifers that meet market specifications are also taken into consideration. The bonuses available under the current Linden Aberdeen Angus Scheme are assumed within the models. These bonuses are comprised of a flat rate component and per kilo component, with levels of payments differing between suckler and dairy bred cattle. Finally, any deductions removed from animal value at slaughter are accounted for in the net revenue values of the finished animals. The slaughter deductions assumed in the models are Levy (LMC), Insurance, Grading Fee, Ard Co Levy (AgriSearch), W.D.C (Waste disposal and collection), Inspection Fee, Clipping, and OTM Additional Insurance. Net revenue values for the sale of cull cows are calculated on model solution on the basis of assumed deadweight, beef price, and slaughter deductions. The assumed beef price for each cull cow is calculated from a reference base price (i.e. the annual average O3 cow price), by taking into consideration price seasonality and grade bonuses/penalties. The annual average O3 cow price within the models is currently set at 72% of the annual average U3 steer price. The seasonal variation in cow price within the models is the same as that assumed for prime cattle. The slaughter deductions assumed applicable to cows are those relating to an over thirty months animal. The net revenue values for the sale of suckled calves and the purchase of drop calves are related to the annual average U3 steer price assumed in the models.

Net revenue values for the sale of finished lambs are calculated on model solution on the basis of carcass weight, deadweight price, and slaughter deductions. The deadweight price for each type of lamb or hogget is calculated from a reference base price (i.e. the annual average U3 lamb and hogget price), by accounting for grade and seasonal variations in price. The seasonal variations in quoted lamb and hogget prices from the average annual quoted lamb and hogget price for 1998-2005 are used within the models to adjust lamb and hogget sale prices for seasonality. The variations in lamb and hogget prices by carcass grade were obtained through the analysis of data for the season 2005/06. These grade price deviations are used in conjunction with the seasonal adjustments specified above to calculate prices for the different lamb and hogget types from the annual average U3 lamb and hogget price assumed within the models. Price bonuses for marketed Scottish Blackface lambs also included within the model. A slaughter deduction of £1 per head is assumed in calculating net revenues for finished lambs or hogget’s. Net revenue values for sale of cull sheep and the sale of store lambs are related to the annual average U3 lamb and hogget price assumed in the models.

## 3.5 Animal diets

Within the models it is assumed that animal diets are a fixed combination of concentrates, straw, silage, and grazed grass. The different cattle feedstuffs options assumed are milk substitute, an 18% protein concentrate, a 17% protein concentrate, a 15% protein concentrate, and a barley/mineral mix. The different sheep feedstuff options assumed includes a breeding ewe concentrate and a lamb finishing mix.

Grassland management options within the models relate to annual fertiliser application rates of 0, 50, 100, 150, or 200 kilograms of nitrogen per hectare on arable or pasture land types. For some of the rough grazing the options is either to apply zero or a small amount of fertiliser. For the remainder of the rough grazing and all other remaining land types no fertiliser is assumed. In terms of conserved forage production within the models the options are either one or two cut silage. It is assumed that dry matter content of silage from both cuts is 22% with a D value of between 60-65. The total dry matter production is assumed at 5.5 tonnes from the 1 cut option and 8.4 tonnes from the 2 cut option.

## 3.6 Utilisation of Livestock Housing

Livestock housing options account for appropriate utilisation of available cubicle house, slatted cattle house, slatted sheep house, and non-specialist loose house resources. Cattle have the option of utilising available housing resources with the exception of specialist sheep housing, whereas sheep cannot use cubicle or slatted cattle housing. For the utilisation of loose housing straw bedding is assumed. Within each model options also exist that allow the provision of additional livestock housing and slurry storage through investment.

### 3.7 Overhead Costs for Beef and Sheep Systems.

Overhead costs applied directly to be beef and sheep options within the models are composed of contract work, machinery running costs, depreciation on machinery and buildings, land maintenance, building repairs, electricity, insurance and other miscellaneous overheads. The level of these costs associated with each beef and sheep option in the models were estimated from data for 149 LFA cattle and sheep farms which participated in the 2005 Farm Business Survey. This involved the running of a simple regression model on the dataset to identify what element of overhead costs varied with level of production and what proportion of overheads appeared to be truly fixed. The level of production was expressed in the regression model as the summation of total cow equivalents in the form of cattle and total cow equivalents in the form of sheep on these farms. Following this, the overhead costs associated with an average Northern Ireland beef cow (i.e. Limousin cross) on a per kilogram basis were determined. Using these estimates of overhead costs on a per kilogram basis the overhead costs for each of the different systems were calculated. These values were applied to each of the associated options within the models and the overhead costs that is totally independent of the level of production was deducted after model solution when calculating farm profit.

### 3.8 Capital Requirements of Beef and Sheep Systems

The capital requirements assumed for each livestock enterprise are composed of the initial purchase price and the variable cost associated with each enterprise until the point of first sale.

### 3.9 Leasing of Resources

Within each model options exist to either rent in or rent out land resources. Land resources are classified as arable, pasture, rough grazing, traditional hay meadow, species rich grassland, wetland, moorland, lowland raised bog, upland breeding wader site, woodland/scrub, or archaeological feature. Options for hiring in or hiring out labour resources are also present in each model. Within each model options also exist to allow the borrowing of working capital on either a current account or term loan. A borrowing limit is also assumed within each farm model.  In addition the option of investing the businesses own working capital is available.

For the leased in of land, the relevant supply functions faced by the business are given as linear functions in the following form:

$PRS_i = ARS_i + BRS_i \, QRS_i \quad \text{all } i$

where: $PRS_i$ is the leasing price of resource i supplied
$QRS_i$ is the quantity of resource i leased in
$ARS_i > 0$ and $BRS_i > 0$

These upward sloping supply functions incorporate within land rental costs (£/ha) the increased transport costs that would be incurred as land is farmed further from the main farm buildings.

For the employment of labour off-farm, the relevant demand functions faced by the business are given as linear functions in the following form:

$PRD_i = ARD_i - BRD_i \, QRD_i \quad \text{all } i$

where: $PRD_i$ is the leasing price of resource i demanded
$QRD_i$ is the quantity of resource i leased out
$ARD_i > 0$ and $BRD_i > 0$

These downward sloping demand functions incorporate within off-farm wage rates (£/hr) the increased transport costs that would be incurred as farm family members travel longer distances from the farm in order to work more hours off-farm.

### 3.10  Meat processing, transportation and marketing costs

The average fixed costs ($AFC_j$) of processing, transportation and marketing meat products j relate to all processing, transportation and marketing costs except labour and raw material (i.e. beef and lamb) costs. These average fixed costs are assumed to take the following form:

$$AFC_j = (FC_j / QP_j) \qquad \text{all } _j$$

where : $FC_j$ = fixed costs and $QP_j$ = quantity processed, transported and marketed

The average variable costs ($AVC_j$) of processing, transportation and marketing meat products j relate to all processing, transportation and marketing costs except labour and raw material (i.e. beef and lamb) costs. These average variable costs are assumed to take the following form:

$$AVC_j = AVP_j + BVP_j \, QP_j \qquad \text{all i}$$

where: $QP_j$ is quantity of meat products j processed, transported and marketed
$AVP_j > 0$ and $BVP_j > 0$

### 3.11 Consumer Demand

For each processed and marketed beef and lamb product, the consumer demand functions faced by the business are given as linear functions in the following form:

$$PPD_j = APD_j - BPD_j \, QPD_j \qquad \text{all j}$$

where: $PPD_j$ = price of processed and marketed beef and lamb product j
$QPD_j$ = quantity of processed and marketed beef and lamb product j demanded
$APD_j > 0$ and $BPD_j > 0$

### 3.12 Agricultural Policy

The various requirements of the Single Farm Payment (SFP), Countryside Management Scheme (CMS), and the Less Favoured Area Compensatory Allowance (LFACA) scheme are incorporated within the models. Therefore for scheme participants all farmed land will be subject to the management prescriptions that are specific to their habitat classification. The levels of payments assumed available under the CMS in the models are set at the levels available in 2007.

To qualify for LFACA payment, the stocking density must have been at least 0.2 LU/ha throughout the entire seven month period 1 April to 31 October. Eligible animals that count towards the stocking density calculation are suckler cows, heifers, breeding ewes, breeding female goats and breeding female farmed deer. The number of heifers that can count as eligible animals under the minimum stocking density limits must be no greater than 40% of the total number of suckler cows and heifers. Producers who have 25% or more of their eligible livestock units as suckler cows/heifers throughout the entire seven month period 1 April to 31 October will receive a bonus payment. Again the number of heifers that can count as eligible animals under the cattle bonus must be no greater than 40% of the total number of suckler cows and heifers. The annual area based payment is currently £40 for each hectare of SDA land and £20 for each hectare of DA land. The cattle bonus is currently paid as an additional payment of 25% of the area payment. Using Farm Business Survey data, an estimate was made of the likely SFP on the representative farm modeled, and was estimated to be £16,198 (including reference and area payments).

### 3.13.1 Farm Household Behaviour- Background and Rationale

Traditionally, the primary focus of agricultural policy within the European Union has been to support farm incomes. Successive Common Agricultural Policy (CAP) reforms have prioritised the promotion and preservation of family farms as a core objective, in response to concerns such as maintaining the fabric of rural society and protecting of the countryside (Commission, 2002). From a European policy perspective the main support mechanisms have focused on the performance and profitability of the farm business. However as in other dimensions of policy, there has been an increased interest in exploring economic well-being from the perspective of the household. For example, the recently established Commission on the Measurement of Economic Performance and Social Progress (CMEPSP) has made a number of recommendations in relation to the development of relevant indicators of social progress and overall well-being. The Commission also acknowledges that ‘well being’ does not rely wholly on income and other material living standards, but also depends on other dimensions such as health, education, personal activities (including work), political voice and governance, social connections and relationships, the environment, etc. (Stiglitz et al., 2009).

Over recent years many farm households have faced the increasing challenge of balancing farm and non-farm work activities as they have sought to maintain household income.  In so doing, farm families make choices and decisions about their level of commitment to the farm business, diversification activities and off farm employment (Jack *et al*., 2009).  As well as undertaking paid employment, farm operators and their partners do a lot of things for themselves, their families and their communities for which they don't get paid, such as caring for others (children and elderly or infirm relatives), housework and voluntary activities.  The increased demands on households' time can have implications for business decisions in relation to how the farm is managed and developed and can also affect farm family lifestyle and well-being.

### 3.13.3  Decision Making and Farm Households

Although farm households are a diverse group, decisions about resource allocation, particularly labour and time-use, will be based on farm, individual and household characteristics.  For example, the size of a farm, the enterprise types or the decision to manage a farm in a more extensive way may result in a lower labour requirement and therefore allowing more labour to be supplied to off-farm employment.   Furthermore, a higher level of human capital and/or the proximity of some farms to larger towns and cities may allow for more off-farm employment opportunities for the members of the household.   The decisions household members make regarding how they divide their time, labour (i.e. the decision to secure off farm employment) and financial resources drive the household's income level and the economic well-being within the household. In managing farm resources, farm operators make important land, enterprise, stock and financial decisions. Therefore farm business decisions, regarding technology adoption and production decisions are increasingly influenced by labour availability within the farm household, (Fernandez-Cornejo et al. 2007).

Time devoted to on and off-farm employment activities, for example on-farm and off-farm activities, compete for limited managerial time (mainly of the operator and spouse). How farm operator households allocate their time largely affects production decisions (such as technology adoption), economic performance, and the household's economic well-being. The decision by farm households to allocate labour to farm and off-farm activities reflects the returns for the alternative use of that labour. The income that the farm operator or spouses can obtain working off-farm is often used to measure the opportunity cost of the operator or spouses farm labour (Fernandez-Cornejo 2007). Increased participation by farm based females in the wider labour market may raise concerns as to how households have adapted. Changing household patterns of employment due to women's increased labour market participation may cause a redistribution effect within the farm household in terms of home production, caring responsibilities, leisure and time spent in farm work (Moss *et al.*, 2004).

This also extends to wider unpaid family labour. Many farm households, particularly dairy farm households, rely on the labour provided by adult children within the household, particularly at critical times throughout the year. If this labour goes off-farm then this may increase the labour demands on the farm operator and spouse (Zepeda and Jongsoog, 2006). Increasing household income may add to farm household resources but it also vies for farm-managerial time, caring time and leisure time. Smith (2002) showed that as the farm operator and other household members engage in off-farm activities, less time is available for farm management. A particular research question which arises is how off-farm employment impacts on the economic performance of farm businesses; for example off-farm income may improve household efficiency but may also impact on farm efficiency.

In terms of farm operators, off-farm work is less likely for those enterprises which are more labour intensive (dairying). Dairy enterprises require long working hours and the opportunity cost of a dairy farmer to go off-farm to work is likely to be higher than for those in other enterprises such as beef and sheep. Increasingly, studies are exploring technology adoption within farm businesses and the factors that influence these decisions. In some cases, labour-using technology has been replaced by capital intensive, labour-saving technology. As farms adopt new technologies of different kinds and at different rates, this may impact on the cost structure, but also the resource allocation decisions for these farms (Chavas 2001; Lu 1985).

Furthermore, current household production decisions by farm operators and their spouses affect future production or consumption possibilities. For example, the accumulation of human capital will increase productivity in the home or wages in the market, so the ability of family members to make medium to long term investment commitments is crucial. In turn this will have implications for how farm families allocate time to farm and off-farm work, other household production activities, leisure and human capital formation.

Previous research has identified that increased demands on households' time can have implications for the farm family lifestyles and well being. Jongsoog and Zepeda (2004) used a Nash-cooperative bargaining framework to examine how members of US family farm households allocate their time between work and leisure. Time allocation categories for parents include farm, off-farm, and household work, as well as leisure time; for children, the categories are farm work and leisure time. Most notably, the results confirm that US women and children make significant labour contributions and that both women and men are decision-makers regarding their own and their children's time allocation. The results also show that intra-household time allocation on US farms is gender specific, and that the father's economic status has the largest impact on the time allocation of household members. The findings also confirm that children's labour makes an important economic contribution to the operation of their family farm.

Incorporating the dimension of 'household time–use' into a profit maximizing beef and sheep farm model and setting it within a spatial framework captures the interplay of farm and nonfarm decisions in terms of farm and non-farm work and other time commitments such as caring and home production. For example, a farmer based on a small beef and sheep farm in a more remote area may wish to seek employment off-farm but depending on his qualifications, where the employment is located and the associated transport costs it may not be economically rational for him to take-up that off-farm employment.

### 3.13.4 Background to Household Time-Use Data

In order to account for how farm household choose to allocate their time and incorporate this into the model, we used data from a farm household survey which was conducted in March 2008. The survey aimed to explore the decisions made by farm operators and their spouses regarding how they use their time. The target sample group was farm operators who were partnered and were likely to have dependent children. The over 65 age group were less likely to have dependent children and were therefore, excluded from the sample selection. The age limits for farm operators were set at between 25 and 65 years. The sample frame focused on the main pastoral based enterprises namely; dairying, cattle and sheep. In order to insure anonymity of all respondents and given the relatively small number of arable and intensive production enterprises in Northern Ireland, these farm households were not included in the final sample selection.

Therefore, the sample selection criteria were as follows:

- Farm operator - married/partnered, aged between 25 and 65 years
- Farm types- Dairy, Beef/Sheep (LFA), Beef/Sheep (Lowland)
- Farm size (SLR) -Greater than or equal to 0.25 SLR

A stratified random sample of 900 farm businesses by farm-type and farm size, provided adequate representation of both ‘full-time’ and ‘part-time’ farm operators. This sample was also selected to be representative spatially across Northern Ireland. The final sample database consisted of 688 farm businesses and 1376 individuals. Of the final sample, 455 were cattle and sheep farms (See table 1).

**Table 1 Farm Household Survey Sample by Farm Type**

| Farm Business Type | n | % |
|---|---|---|
| Dairy (LFA & Lowland) | 233 | 33.9 |
| Cattle & Sheep (SDA, DA & Lowland) | 455 | 66.1 |
| **Total** | **688** | **100** |

### 3.14**Own Resources Available**

The levels of land, labour, working capital, and livestock housing resources assumed owned within the model were determined from the dataset of the LFA farm survey undertaken. Land resources owned are categorized as either arable, pasture, rough, species rich grassland, traditional hay meadow, wetland, moorland, lowland raised bog, upland breeding wader site, woodland/scrub, or archaeological feature. In line with Nitrate Directive regulations the maximum level of organic nitrate production per farm is assumed at 170 kilograms per hectare. Levels of the different types of land owned and the maximum organic nitrate production assumed on owned land on the representative farm is shown in table 2. Livestock housing resources available on each representative farm are categorised as cubicles, slatted cattle, slatted sheep, and loose housing. Additionally a quantity of slurry capacity is also available on each representative farm. The farmer, spouse, and other family members are each assumed to supply a specified amount of labour (hours) which is available for farm work, off-farm work, child care, caring for others, and home production. These labour availability data were taken from the AFBI farm household survey discussed above. The levels of own capital assumed available to finance livestock, working capital, and machinery are also shown in table 1. These levels of own capital available for each representative farm were estimated using data from 149 LFA Cattle and Sheep farms within the 2005 Farm Business Survey dataset. This involved the estimation of a regression model that expressed total owned working capital availabilities as a summation of cow equivalents in the form of cattle and cow equivalents in the form of sheep. Owned working capital availabilities were in the form of livestock, crops, machinery, feedstuffs, fertilisers, debtors, savings etc. Own working capital availabilities were then estimated from their cow equivalents cattle and cow equivalents sheep. Any additional resource requirements can only be met through the leasing of conacre, hiring of labour, investing in livestock housing, and borrowing capital.

**Table 2: Own Resources in Representative Farm Model.**

| | | | |
|---|---|---|---|
| **Land Owned** | | **Housing** | |
| Land Area Owned (ha) | 53.09 | Cubicle House Places (Cows) | 36 |
| | | Slatted Cattle Accommodation (m2) | 239 |
| **Breakdown of owned land** | | Loose Accommodation (m2) | 67.47 |
| Arable area (ha) | 33.87 | Slatted Sheep Accommodation (m2) | 22.15 |
| Pasture area (ha) | 10.83 | Slurry Storage Capacity (m2) | 705 |
| Rough Grazing area (ha) (includes common) | 5.05 | | |
| Species Rich Grassland (ha) | 0 | **Owned Working Capital** | |
| Traditional Hay Meadows | 0 | CE Cattle | 97.88 |
| Wetland (ha) | 0 | CE Sheep | 15.35 |
| Moorland(ha) | 2.78 | Total OWC (£) | 66,210 |
| Lowland Raised bog (ha) | 0 | | |
| Upland Breeding Wader Site (ha) | 0.44 | **Family Labour** | |
| Woodland/Scrub (ha) | 0.10 | Annual labour available from farmer (hrs) [1] | 3729 |
| Archaeological feature (ha) | 0.02 | Annual labour available from spouse (hrs) [1] | 4009 |
| | | Annual labour available from other family (hrs) [2] | 623 |
| **LFA Breakdown** | | | |
| SDA (% Total Land Farmed) | 43.49 | | |
| DA (% Total Land Farmed) | 52.76 | | |
| Non-LFA (% Total Land Farmed) | 3.75 | | |
| | | | |
| **Organic N Limit** | | | |
| N Limit (kg)-owned land | 9,025 | | |
| | | | |

[1] Labour available for farm work, off-farm work, child care, caring for others, and home production (AFBI farm household survey).

[2] Labour only available for farm work and off-farm work (AFBI farm household survey).

## 4. Discussion of Results

Solution the farm model identifies the overall farming system that achieves the maximum profit under the base assumptions. Following this, the model can be solved under alternative scenarios, where the assumptions relating to product prices, input prices, borrowing constraints, off-farm wage rates, levels of farm payments etc. are subjected to sensitivity analysis. Within these simulations the assumptions were made that the land must be maintained in good agricultural condition for Single Farm Payment purposes. Additionally it is assumed that the farmer participates in the Countryside Management Scheme. All model results reported below assume (1) an annual average U3 steer price of £2.00 per kg, and (2) an annual average U3 lamb and hogget price of £2.50 per kg. The farm and off-farm income figures reported in Tables 2 and 3 includes profit/income generated from farming activities, direct consumer sales, Single Farm Payment, Countryside Management Scheme, the Less Favoured Area Compensatory Allowance scheme, off-farm investment, and off-farm employment.

Table 2 illustrates how the model results are influenced by changing assumptions about the land rental market. The model compares the baseline solution, which assumes constant land leasing costs (£/ha), with a scenario where the farm business faces upward sloping land leasing costs (i.e. average leasing costs increase as more land is leased). These upward sloping supply functions incorporate within land rental costs (£/ha) the increased transport costs that would be incurred as land is farmed further from the main farm buildings. It is clear from Table 2 that the cost of leasing in additional land has a large impact on the economic viability of farmer direct sales to the consumer. If the farm business only markets beef and lamb that has been produced on its own farm then its ability to economically expand production is linked to the costs of leasing in additional land. However, a relatively large output may be required in order to lower average fixed costs of processing and marketing meat to a level where the farm supplier of beef and lamb is competitive in the market. The fixed costs of selling meat direct to consumers would include, for example, buildings, equipment, vehicles, insurance and minimum levels of marketing activities. In the case presented in Table 2, the increased costs of farming more distant land removes the economic viability of farmer direct sales to the consumer. Interestingly, the total farm and off-farm income is little changed, although this depends on a substantial change in farm enterprises and the farmer working a lot more off-farm.

Table 3 illustrates how the model results are influenced by changing assumptions about the off-farm labour market. The model compares the baseline solution, which assumes constant off-farm wage rates (£/hr), with a scenario where the farm business faces downward sloping off-farm wage rates (i.e. average off-farm wage rates decrease as more hours are worked off-farm). These downward sloping demand functions incorporate within off-farm wage rates (£/hr) the increased transport costs that would be incurred as farm family members travel longer distances from the farm in order to work more hours off-farm. In making the decision, for example, as to whether a farm business should commence marketing its beef and lamb direct to consumers, the farm family would consider if their available labour resources would be better employed in off-farm employment. The level of travel costs associated with off-farm employment is likely to impact on this decision. Table 3 indicates that in this case the change in assumptions about off-farm labour markets have relatively little impact on farming activities but does impact on the work patterns of the farm family. There is a small move away from cattle production in favour of more sheep production, however, the farm business remains involved in farmer direct sales to the consumer with farm and off-farm income little changed. However, the pattern of off-farm employment between farmer and spouse is changed, although by a relatively modest degree. Of course, any increase in transport costs, above the levels assumed in this scenario, are likely to produce a more significant variation from the base model solution. Nevertheless, the model results illustrate that the assumptions about the availability of off-farm work in terms of distance from the farm, and associated travel costs, can impact on the work patterns and economic wellbeing of the farm family.

Farm models that incorporate the spatial dimension are likely to be useful, and possibly necessary, in the analysis of many important policy issues, for example, (1) structural change in agricultural production, (2) farm diversification, (3) carbon foot-printing, (4) farm family wellbeing, etc. At the most basic level, the spatial dimension could/should be integrated into farm business models through the explicit incorporation of transport costs. One of the main merits in at least taking account of transport costs is that they can be estimated using relatively straightforward quantitative methods (e.g. Anderson, 1998).

The major disadvantage with the type of general non-linear optimization models employed in this paper is that they can be very temperamental. That is, a relatively modest change in a parameter, or the model structure, can result in the model suddenly not solving or taking a very long time to solve. This is particularly irksome if any realistic sensitively analysis of the baseline model results is to be done. There are a number of strategies that can be adopted which may help to alleviate these problems, for example, (1) have a selection of global solvers available, (2) try to construct well behaved models, (3) think carefully about the type and extent of any sensitivity analysis, and (4) assume that any sensitivity analysis may take a substantial amount of time to complete.

## Table 2 Model Simulations: Land Rental Market

| | **Base Model (i.e. Constant Land Leasing Costs - £/ha)** | **Model with Increasing Land Leasing Costs (£/ha)** [1] |
|---|---|---|
| **Farm Enterprises** | | |
| Beef Cows (hd) | 43 | 9 |
| Other Cattle (hd) | 84 | 10 |
| Breeding Ewes (hd) | 72 | 187 |
| Other Sheep (hd) | 28 | 17 |
| **Livestock Sales** | | |
| Store cattle (hd) | - | 4 |
| Finished cattle (hd) | - | 4 |
| Store lambs (hd) | 5 | 95 |
| Finished lambs (hd) | 9 | 138 |
| **Meat Processing** | | |
| Cattle processed (hd) | 40 | - |
| Lambs processed (hd) | 75 | - |
| Total meat processed (kg) | 13,121 | - |
| **Direct Consumer Sales** | | |
| Beef – standard (kg) | 5,487 | - |
| Beef – AA (kg) | 6,078 | - |
| Lamb – standard (kg) | 1,265 | - |
| Lamb – SBF (kg) | 291 | - |
| **Resource Use** | | |
| Total land farmed (ha) | 246 | 53 |
| Land leased in (ha) | 193 | - |
| Labour hired (hrs) | - | - |
| Farmer off-farm work (hrs) | 408 | 1,800 |
| Spouse off-farm work (hrs) | 814 | 814 |
| Others off-farm work (hrs) | 623 | 623 |
| Capital borrowed (£) | - | - |
| Capital invested (£) | - | 27,749 |
| **Farm & Off-farm Income (£)** | 48,200 | 47,862 |

**Note:**

1. Upward sloping land leasing supply curves – i.e. land leasing costs are assumed to increase due to increased transport costs associated with farming additional leased land. All other parameters are set at base model values.

## Table 3 Model Simulations: Off-farm Labour Market

| | Base Model (i.e. Constant Off-Farm Wage Rates - £/hr) | Model with Decreasing Off-Farm Wage Rates (£/hr) [1] |
|---|---|---|
| **Farm Enterprises** | | |
| Beef Cows (hd) | 43 | 42 |
| Other Cattle (hd) | 84 | 83 |
| Breeding Ewes (hd) | 72 | 77 |
| Other Sheep (hd) | 28 | 30 |
| **Livestock Sales** | | |
| Store cattle (hd) | - | - |
| Finished cattle (hd) | - | - |
| Store lambs (hd) | 5 | 5 |
| Finished lambs (hd) | 9 | 9 |
| **Meat Processing** | | |
| Cattle processed (hd) | 40 | 39 |
| Lambs processed (hd) | 75 | 80 |
| Total meat processed (kg) | 13,121 | 13,071 |
| **Direct Consumer Sales** | | |
| Beef – standard (kg) | 5,487 | 5,383 |
| Beef – AA (kg) | 6,078 | 6,033 |
| Lamb – standard (kg) | 1,265 | 1,335 |
| Lamb – SBF (kg) | 291 | 321 |
| **Resource Use** | | |
| Total land farmed (ha) | 246 | 247 |
| Land leased in (ha) | 193 | 194 |
| Labour hired (hrs) | - | - |
| Farmer off-farm work (hrs) | 408 | 602 |
| Spouse off-farm work (hrs) | 814 | 610 |
| Others off-farm work (hrs) | 623 | 613 |
| Capital borrowed (£) | - | - |
| Capital invested (£) | - | - |
| **Farm & Off-farm Income (£)** | 48,200 | 48,293 |

**Note:**

1. Downward sloping off-farm labour demand curves – i.e. average wage rates are assumed to decrease due to the increased travel costs associated with additional off-farm employment. All other parameters are set at base model values.

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