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What LFA beef and sheep farmers should do and why they should do it.

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Abstract

This paper describes how representative farm business models were employed to identify optimal beef and sheep production systems for Less Favoured Area (LFA) farms in Northern Ireland. The bio-economic models identify the optimal farming system for theses farms under various market and policy assumptions. They are useful, therefore, in helping to develop industry strategy. The models indicate that, under current market and policy conditions, a dairy-based beef system is likely to be the most profitable beef enterprise. However, depending on land quality and livestock housing resources, and the market and policy environment, suckler-based beef systems can also feature in the profit maximising enterprise mix. The results also suggest that the optimal sheep system is consistent with the stratified sheep systems traditionally operated in Northern Ireland. In general, beef production appears to have some advantages over sheep production where, depending on relative prices and resource availabilities, it is often better to replace sheep with cattle and employ the released labour off-farm, than to replace cattle with sheep and invest the released capital off-farm. In some situations, farmers should significantly reduce their capital and labour inputs to the farm business by substantially reducing stocking rates or even abandoning land completely.

1. Introduction

Land is currently designated as Less Favoured Area (LFA) mainly on the basis of agricultural disadvantage, namely, soil, climate and topography. Much of the landscape character in the LFA has been created, and is sustained, by agricultural activity. Hence, the rationale for a Less Favoured Area Compensatory Allowance (LFACA) scheme is that the areas most at risk of losing agricultural activity, and consequently suffering degradation of landscape character, are those which suffer the greatest physical challenges. This report presents the results obtained in an exercise undertaken to examine how profit maximising beef and sheep farms would react to changes in market and policy conditions. In reaching optimal profit maximising solutions consideration is given to the full complement of traditional cattle and sheep systems that are feasible within the studied sector. Optimal solutions are obtained under full consideration of the current policy environment and differing assumptions relating to the implementation of the LFACA.

In identifying optimal farming systems for LFA beef and sheep farms the key factors for consideration relate to (1) production costs, (2) markets and marketing, and (3) agricultural policy. The likely ways that these factors might have an influence on the optimal farming systems for Northern Ireland's LFA beef and sheep farm sector are briefly discussed below.

1.1 Production Costs

Within LFA beef and sheep farms the diet formulations of livestock systems are composed of grazed grass, silage and concentrates. In intensive systems the main diet component is concentrates whereas in extensive systems it is grazed grass. Therefore, the relative costs of grazed grass, silage and concentrates will influence the choice of optimal farming system. The cost of producing grazed grass is determined by land and fertiliser prices. Silage costs are also dependent on land and fertiliser prices but also contractor charges and storage costs. In the case of LFA farms, there is little home production of concentrates and so their cost is determined mainly by the purchase price plus some costs associated with storage.

Another important factor that affects profitability of farming systems is the cost of labour. Variations exist in the levels of labour utilised by different farming systems and therefore the cost of hired labour will affect their relative profitability. In addition to this, there is also the possibility of deploying family labour resources to off-farm employment and therefore an opportunity cost exists in utilising labour resources for farming systems. For the purposes of this study the opportunity cost of family labour resources is assumed to be dependent upon the off-farm wage rate. For breeding beef cow and ewe enterprises there are possibilities of operating indoor or outdoor wintering systems. In comparison, indoor systems involve housing facilities but, arguably produce more efficient use of labour resources. Therefore, the profitability differences of the two systems will be dependent upon the cost of housing, labour, and product prices.

For the operation of any farming system capital is required which can be made available from own resources or borrowed. The level of capital required by a specific farming system is dependent on the levels of inputs that it requires and their associated costs. Therefore, the relative profitability of farming systems will be affected by the cost of capital i.e. interest rates. In cases where owned capital is used an opportunity cost also exists as the capital could be invested in non-farm investments.

1.2 Markets & Marketing

During the beef export ban from 1996-2006 almost all cattle produced on Northern Ireland farms were slaughtered and the beef consumed within the United Kingdom. Since the lifting of the ban in March 2006, a modest increase in beef exports has been experienced. Sheep produced on Northern Ireland farms have traditionally been sold to slaughterhouses in Northern Ireland, Republic of Ireland, and Great Britain. In addition to exports there have also been imports of live cattle and sheep for slaughter into Northern Ireland from Great Britain and the Republic of Ireland.

With the lifting of the beef export ban in 2006 new market opportunities will become available for Northern Ireland beef. For individual Farm Quality Assured farms in Northern Ireland the option exists to produce beef for either niche or standard commodity markets. Niche marketing opportunities exist in NI/GB for certified Angus or Hereford beef. In producing for these niche markets farmers can at present avail of price premiums for certified cattle that meet market specifications. A major consideration is the maximum level of sector supply at which these premiums can be sustained. On the lamb marketing side only standard commodity markets exist for Northern Irelands farmers at present. At the individual farm level decisions must therefore be made on how best to reduce the costs of producing what is essentially a standard commodity product.

1.3 Agricultural Policy

Agricultural policies relevant to Northern Ireland's LFA beef and sheep sector take the form of subsidies, regulations, and price supports. Subsidies and other transfers are paid via the Single Farm Payment Scheme, Countryside Management Scheme (CMS) and Less Favoured Area Compensatory Allowance Scheme (LFACA). Under the Single Farm Payment farmers receive an annual payment subject to meeting cross-compliance requirements. Through membership of CMS farmers receive payments subject to adhering to a farm specific management plan that may incorporate habitat stocking densities, closed grazing periods, and fertiliser application limits. Finally under the LFACA scheme farmers receive area payments subject to meeting minimum stocking density requirements for a seven month period. In selection of an optimal farming system decisions will have to be made regarding the uptake of these schemes given their associated payments and pre-conditions.

Another policy measure facing LFA beef and sheep farms at this point in time is the Nitrates Directive. Under this, farmers are subject to restrictions that limit the spreading period and application rate of organic and inorganic fertilisers, set minimum manure storage capacities, and require record keeping. The Nitrate Directive regulations therefore adds to the complexity of selecting an optimal farming system in that it limits the animal numbers that can be present but also requires that adequate slurry capacity is present to cover storage requirements for a defined period.

Northern Ireland LFA Beef and Sheep farmers additionally may receive support indirectly in the form of export refunds on their produce exported outside the European Union and also higher domestic prices through the application of tariffs on imports. The weakening of these price support mechanisms is likely to result in lower prices for beef and sheep products.

2. Identifying Representative LFA Beef and Sheep Farms

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).

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%). Therefore, it is important that these small farms should be included in any farm modelling exercise aimed towards identifying appropriate business advice or public policy for this sector of the industry.

3. Developing representative LFA beef and sheep farm models

This section details the development of a representative farm model for each group of homogeneous farms discussed in section 2. Physical and financial assumptions about the different farming options incorporated within each 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 each representative farm model are based upon data obtained from the LFA beef and sheep survey undertaken.

3.1 Description of Production Options Evaluated

Within each representative farm model different options exist in relation to cattle rearing, sheep rearing, marketing, livestock housing, land, labour, working capital, and agricultural policy. Upon solution each farm model selects the levels of these different options that formulate an overall profit maximising farming system. Within this section a description is given of the options included in each representative farm model.

3.2 Beef Cows and Replacement Heifers

The models currently contain three 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 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 third option also involves 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 February and a sale/transfer date of 1st November are assumed. It is also assumed that no distinctive differences exist between the suckled calves produced by the traditional breed housed and the traditional breed out-wintered.

Within the models there are two 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 and the second option is the rearing of spring calving traditional type (i.e. Angus cross) replacement heifers. It is assumed under both options that replacement heifers are sourced from the dairy herd, housed during the winter period, artificially inseminated, and calve at 24 months.

3.3 Suckled Calf Rearing and Finishing

Within the models options exist for the finishing of suckled calves produced by the beef cow options outlined in section 3.2. For suckled calves the finishing options are bulls at 13 or 15 months, steers at 18, 24, 30, or 36 months, and heifers at 18, 24, or 30 months. Continuous housing after weaning is assumed in the bull beef options, whereas housing in the winter period only is assumed for the steer and heifer options

3.4 Dairy Calf Rearing and Finishing

The farm models also include options that allow the finishing of calves purchased from commercial dairy herds. Steer and bull options involve continental (e.g. Charolais or Limousin), traditional (e.g. Angus), and Friesian breed calves, whereas the heifer options involve continental (e.g. Charolais or Limousin) and traditional (e.g. Angus) bred calves. It is assumed that the dairy sourced calves have an average birth date of 1st January. The finishing options for dairy sourced calves are as bulls at 13 or 15 months, steers at 18, 24, 30, or 36 months, and heifers at 18, 24, or 30 months. Again it is assumed that bull beef options involve continuous housing, whereas steers and heifers are only housed during the winter period.

3.5 Breeding Sheep

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. The second option is a Scottish Blackface ewe crossed with a Border or Blue Leicester ram. The third option is a Scottish Blackface ewe crossed with a Texel ram. The fourth option is a crossbred ewe crossed with a Suffolk ram. 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 the average lambing date is the 1st April with store lambs being 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 option involves 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.

3.6 Store Lamb Finishing

Within each model there are different options for the finishing of store lambs produced by the breeding ewe systems outlined in 3.5 above. 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. It is assumed that lambs enter these options on the 1st September at 14 kilograms halve weight. The third set of options relate to the finishing of store lambs on grass. It is assumed that lambs enter this option on the 1st September at 16 kilograms half weight.

3.7 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 upon 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, heifers, and bulls 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 upon 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 upon model solution on the basis of carcase 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. 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.

3.8 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 are 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.

3.9 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.

3.10 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. The costs of hiring in labour are assumed at the minimum agricultural wage rate, while the net revenue for hiring out labour resources is assumed equal to the minimum national wage rate. 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.

3.11 Agricultural Policy

Pre-conditions of the Single Farm Payment (SFP), Countryside Management Scheme (CMS), and where appropriate 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. An estimate was made of the SFP on the 10 representative farms. These estimates were calculated using Farm Business Survey data, and are reported in Table 1 below.

Table 1: Single Farm Payments Rates by Farm Cluster/Model[1]

Farm Cluster/Model	Estimated Value of Single Farm Payment (£)
1	2,371
2	4,970
3	5,465
4	9,249
5	49,897
6	28,500
7	16,198
8	30,604
9	37,849
10	13,302

[1]. Includes Reference and area amounts. Estimated from LFA Beef and Sheep farm survey data.

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.

3.12 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 are totally independent of the level of production was deducted after model solution when calculating farm profit.

3.13 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.

3.14 Resources Available on Representative Farms

The levels of land, labour, working capital, and livestock housing resources assumed owned within each 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 of each 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 capacities of these different housing types and their associated total slurry capacity available on each representative farm are shown in table 3. For each representative farm the farmer and other family members that currently work on the farm are used to calculate potential labour availabilities. In line with Nix (2005) it is assumed that the farmer could provide 300 standard man-days per year, whereas other family members could provide 275 standard man-days per year. One standard man-day is equal to eight hours. The number of workers available to each representative farm and the total annual hours of labour hours assumed are shown in table 2. The levels of own capital assumed available to finance livestock, working capital, and machinery on each representative farm are also shown in table 3.

Table 2: Land Resources

	Farm Cluster/Model									
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Land Owned										
Land Area Owned (ha)	14.41	21.42	44.36	39.05	162.69	98.5	53.09	419.67	201.94	128.3
Breakdown of owned land										
Arable area (ha)	9.94	13.47	18.54	23.12	109.82	63.63	33.87	44.5	47.66	24.25
Pasture area (ha)	0.73	4.15	4.16	5.69	17.65	20.34	10.83	35.05	32.85	8.03
Rough Grazing area (ha) (includes common)	1.23	1.57	8.7	6.196	4.35	5.67	5.055	24.81	80.84	70.35
Species Rich Grassland (ha)	0.26	0.16	0.23	0.14	0	0	0	0	0	0.66
Traditional Hay Meadows	0.0073	0.19	0	0.13	0	0	0	0	0.41	0.33
Wetland (ha)	0.04	0.36	0.14	0.32	0	1.58	0	0	0	0
Moorland(ha)	0.72	0.49	11.94	2.21	9.91	2.9	2.78	298.2	14.31	23.21
Lowland Raised bog (ha)	0.02	0.032	0	0.02	0	0	0	0	0	0
Upland Breeding Wader Site (ha)	0.70	0.78	0.26	0.98	19.83	0.19	0.44	15.31	24.77	0
Woodland/Scrub (ha)	0.76	0.21	0.37	0.23	1.13	4.13	0.1	1.8	1.1	1.41
Archaeological feature (ha)	0.0036	0.008	0.02	0.014	0	0.06	0.0154	0	0	0.06
LFA Breakdown										
SDA (% Total Land Farmed)	49.83	59.1	83.88	53.97	72.66	80.0	43.49	84.7	85.0	95.8
DA (% Total Land Farmed)	49.35	40.85	16.12	43.67	25.5	20.0	52.76	1.18	15.0	3.32
Non-LFA (% Total Land Farmed)	0.82	0.05	0	2.37	1.84	0	3.75	14.11	0	0.88
Organic N Limit										
N Limit (kg)-owned land	2,450	3,641	7,541	6,639	27,657	16,745	9,025	71,344	34,330	21,811

Table 3: Housing, owned working capital, and family labour.

	Farm Cluster/Model									
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Housing										
Cubicle House Places (Cows)	5.86	12.71	2.25	14.16	88	83.6	35.77	0	35	0
Slatted Cattle Accommodation (m2)	37.13	59.95	67.88	118.15	552.83	117.45	239	61.97	252	88.67
Loose Accommodation (m2)	32.49	34.19	66.15	76	179.8	110.28	67.47	77	0	18.56
Slatted Sheep Accommodation (m2)	6.09	2.15	68.63	10.94	0	0	22.15	274.5	0	163.8
Slurry Storage Capacity (m2)	110	184	256	322	1554	661	705	673	682	505
Owned Working Capital										
CE Cattle	11.06	28.17	16.37	50.34	264.4	142.04	97.88	25.4	184.7	33.48
CE Sheep	2.8	1.55	25.33	6.82	8.3	5.20	15.35	243.2	111.4	76.06
Total OWC (£)	7,885	17,968	19,700	33,645	166,281	89,609	66,210	107,845	156,181	49,484
Family Labour										
Number of other full-time/part-time individuals working on farm other than respondent	0.25	0.451	0.35	0.7045	0.5	0.8	0.692	0.5	2.5	0.8
Annual labour available from farmer (hrs) [1]	2400	2400	2400	2400	2400	2400	2400	2400	2400	2400
Annual labour available from other workers (hrs) [1]	550	992	770	1550	1100	1760	1522	1100	5500	1760
Total annual labour available (hrs)	2950	3392	3170	3950	3500	4160	3922	3500	7900	4160

[1] Farm Management Pocketbook

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 on each farm is in the form of livestock, crops, machinery, feedstuffs, fertilisers, debtors, savings, borrowings etc. The own working capital availabilities on each representative farm were then estimated from their cow equivalents cattle and cow equivalents sheep. Any additional resource requirements for each farm can only be met through the leasing of conacre, hiring of labour, investing in livestock housing, and borrowing capital.

4. Discussion of Results

The representative farm models outlined in chapter three are solved using the GAMS/CPLEX mathematical programming software package (Brooke et al., 1998). GAMS (General Algebraic Modelling 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. Optimisation models created with GAMS must be solved with a programming algorithm, and CPLEX is used in this case. Upon solution each representative farm model identifies the overall farming system that achieves the maximum profit under the base assumptions. Following this, the models 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.

4.1 System Results for Model 4 under LFACA scheme with cattle bonus

The optimal system for representative model 4 is presented in Table 4. The rationale for presenting detailed simulations from representative farm model four is because its characteristics are close to the average of the farms surveyed in the LFA farm survey. It is assumed 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. Finally, 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. Table 4 illustrates that within the optimal solution the farming enterprises consist of buying in and finishing Angus x Friesian heifer drop calves at 24 months and operating a small Angus suckler herd.

In addition to identifying the optimal farming system, the model simulation also identifies the relative profitability of the other beef and sheep systems considered within the model. Therefore, table 5 presents the relative profitability of all beef and sheep systems under the base scenario. The values show the increase in profitability per head required for that system to be equal in profitability with the optimal system. Most noteworthy is the finding that, although not in the optimal plan, breeding ewes (in particular, Scottish Blackface ewes crossed with a Leicester ram) are close to being included.

Table 4: Optimal System: Model 4 under LFACA with Cattle Bonus

Activity	System
Area Farmed (ha)	39.05
Land Leased in (ha)	0
Suckler Beef cow (no.)	6
Male Cattle Finished (no.)	0
Female Cattle Finished (no.)	36[2]
Breeding Ewes (no.)	0
Replacement Ewe Lambs (no.)	0
Lambs Finished (no.)	0
Capital Borrowed (£)	0
Capital Invested off farm (£)	15,936
Labour hired in (hrs)	0
Off-farm employment (hrs)	2,884
Increased investment in on-farm livestock housing (£)	0
Farm Resource Income (£) [1]	26,016

1. Includes Single Farm payment.
2. 33 Dairy-bred Angus heifers plus 3 Suckler-bred Angus heifer all finished at 24 months

4.2 Changes in Farm Incomes under different LFACA assumptions

Table 6 reports the farm profit, and Table 7 the farm resource income, generated by each of the 10 representative farm models with (1) the LFACA scheme with a cattle bonus, (2) the LFACA scheme with no cattle bonus, and (3) no LFACA scheme. Farm profit includes any profit (loss) generated by farming activities; plus any income generated from CSM and (where indicated) LFACA schemes. Farm resource income includes farm profit (as defined above), investment income from surplus working capital, income from off-farm employment and the SFP. The following observations can be made:

§ It is optimal for all farms to manage the farm in order to qualify for the cattle bonus, as in each farm type higher profits are being generated under the cattle bonus option. In reality, we know that a significant number of farms choose to operate sheep-only systems. As a very large number of these LFA beef and sheep farms are farmed on a pert-time basis, the added management complications of running a second enterprise may not be justified by a marginal increase in farming profits. The loss of the cattle bonus will reduce farm profit on all farms, but by a relatively small amount in some cases.

§ The loss of the LFACA scheme results in a further reduction in farm profits on all farms. The magnitude of this reduction in farm profits is most significant on some of the larger farms. Therefore, although these larger farms represent a relatively small percentage of the total population, the quite large reductions in individual farm profit caused by the removal of the LFACA scheme results in a sizable reduction in farm profits at the sector level.

§ In almost all farm types the reduction in farm family income resulting from the removal of the LFACA scheme is less when measured by changes in farm profit rather than by changes in the broader measure of farm resource income (farm profit is included within farm resource income). That is, the loss of farm family income results not just from the reduction in farm profits but also through a reduction in the income earned through the employment of any surplus family labour and working capital off-farm. In this particular policy simulation, the farmers should react to the loss of the LFACA scheme, and its associated management restrictions, by choosing more profitable farm enterprises. However, in this case, these more profitable enterprises require a larger commitment of capital and/or labour resources. This reduces the amount of these resources that are available to earn income off-farm. One strategy that farmers could employ to alleviate this problem to some extent, would be to develop beef and sheep enterprises that require less capital and labour than the standard systems currently operated on most farms. That is, farmers could employ more extensive and easy care technologies on-farm, and earn additional income off-farm from any working capital and labour that was released from farming operations.

4.3 Changes in Farming Systems

Table 8 reports the change in farming system on each of the 10 representative farm models with (1) the LFACA scheme with a cattle bonus, (2) the LFACA scheme with no cattle bonus, and (3) no LFACA scheme. The following observations can be made:

- The cattle bonus clearly encourages the mixed grazing of cattle and sheep on rough grazing as its removal causes the reduction, or total removal, of suckler cows from some of the larger farms. This is because the model makes the reasonable assumption that suckler cows are the only type of cattle that can utilize rough grazing and still meet their production targets.

- Mixed grazing is totally eliminated on rough grazing on all farm types with the removal of the LFA scheme. That is, suckler cows do not feature in the profit maximizing system on any of the farms. The reduction in suckler cows is accommodated to some extent on the better land by increasing numbers of other cattle.

- Breeding ewes and other sheep either remain unchanged or are increased with the removal of the cattle bonus. In contrast, sheep numbers actually fall on some farms with the removal of the LFACA scheme. This is because breeding ewes are not required to satisfy any minimum stocking rate requirements.

Table 5: Relative Profitability of Systems: Model 4 under LFACA with Cattle Bonus

System	Relative Profitability (£)
Continental Suckler Cow x Continental Bull – Housed	-8.56
Angus Suckler Cow x Angus Bull –Housed	optimal
Angus Suckler Cow x Angus Bull –Out wintered	-7.20
13 month Continental Suckler bull	-72.21
15 month Continental Suckler bull	-11.51
18 month Continental Suckler Steer	-95.78
24 month Continental Suckler Steer	-99.12
30 month Continental Suckler Steer	-161.69
36 month Continental Suckler Steer	-229.66
13 month Angus Suckler bull	-89.00
15 month Angus Suckler bull	-39.68
18 month Angus Suckler Steer	-3.83
24 month Angus Suckler Steer	-27.40
30 month Angus Suckler Steer	-96.62
36 month Angus Suckler Steer	-170.77
18 month Continental Suckler Heifer	-29.40
24 month Continental Suckler Heifer	-29.01
30 month Continental Suckler Heifer	-138.45
18 month Angus Suckler Heifer	-78.26
24 month Angus Suckler Heifer	Optimal
30 month Angus Suckler Heifer	-111.40
13 month Friesian bull	-193.03
15 month Friesian Dairy bull	-134.03
18 month Friesian Dairy Steer	-29.93
24 month Friesian Dairy Steer	-67.93
30 month Friesian Dairy Steer	-107.88
36 month Friesian Dairy Steer	-159.72
13 month Continental Dairy bull	-206.01
15 month Continental Dairy bull	-136.04
18 month Continental Dairy Steer	-54.06
24 month Continental Dairy Steer	-67.42
30 month Continental Dairy Steer	-132.24

Table 5 (cont'd)

System	Relative Profitability (£)
36 month Continental Dairy Steer	-172.33
13 month Angus Dairy bull	-226.25
15 month Angus Dairy bull	-168.55
18 month Angus Dairy Steer	-61.75
24 month Angus Dairy Steer	-47.52
30 month Angus Dairy Steer	-116.90
36 month Angus Dairy Steer	-166.10
18 month Continental Dairy Heifer	-63.78
24 month Continental Dairy Heifer	-37.18
30 month Continental Dairy Heifer	-121.46
18 month Angus Dairy Heifer	-74.25
24 month Angus Dairy Heifer	Optimal
30 month Angus Dairy Heifer	-85.11
Blackface ewe x Blackface ram	-13.65
Blackface ewe x Leicester ram	-0.10
Blackface ewe x Texel ram	-6.78
Crossbred ewe x Texel ram	-12.86
Blackface Store Lamb Finished on grass	-4.49
Blackface Store Lamb Finished on grass & concentrates	-2.70
Blackface Store Lamb Finished Indoors	-12.35
Leicester X Blackface Store Lamb Finished on grass	-4.41
Leicester X Blackface Store Lamb Finished on grass & concentrates	-2.52
Leicester X Blackface Store Lamb Finished Indoors	-14.29
Texel X Blackface Store Lamb Finished on grass	-4.72
Texel X Blackface Store Lamb Finished on grass & concentrates	-2.29
Texel X Blackface Store Lamb Finished Indoors	-13.97
Texel X Crossbred Store Lamb Finished on grass	-3.95
Texel X Crossbred Store Lamb Finished on grass & concentrates	-0.18
Texel X Crossbred Store Lamb Finished Indoors	-12.50

Table 6 Farm Profit[1] under various LFACA assumptions

Model	Farm Profit LFACA with Cattle Bonus (£)	Farm Profit LFACA no Cattle Bonus (£)	Farm Profit No LFACA (£)	Diff. (col. 4 minus col. 2)	Percent. of Sector (%)	Total Sector[2] Change (£ k)
1	-3,322	-3,430	-3,592	-270	28	-1,134
2	-1,869	-2,040	-2,218	-349	25.5	-1,335
3	889	488	-662	-1,551	10	-2,326
4	820	524	203	-617	22	-2,036
5	17,508	16,119	12,724	-4,784	1	-718
6	9,891	9,470	5,924	-3,967	2.5	-1,488
7	3,594	3,223	3,134	-460	6.5	-448
8	38,684	35,669	20,463	-18,221	1	-2,733
9	22,188	20,231	15,747	-6,441	1	-966
10	9,862	8,074	3,792	-6,070	2.5	-2,276

Notes
[1]Farm profit includes any profit (loss) generated by farming activities, plus any income generated from CSM and (where appropriate) LFACA.
[2]Assumes the LFA beef and sheep farm sector contains approximately 15,000 farms.

Table 7 Farm Resource Income[1] under various LFACA assumptions

Model	Farm Resource Income: LFACA with Cattle Bonus (£)	Farm Resource Income: LFACA no Cattle Bonus (£)	Farm Resource Income: With No LFACA (£)	Diff. (col. 4 minus col. 2)	Percent. of Sector (%)	Total Sector[2] Change (£ k)
1	12,698	12,590	12,325	-373	28	-1,567
2	17,921	17,750	17,275	-646	25.5	-2,471
3	18,527	18,126	16,696	-1,831	10	-2,747
4	26,016	25,720	25,071	-945	22	-3,119
5	69,738	68,349	64,885	-4,853	1	-728
6	44,297	43,759	40,213	-4,084	2.5	-1,532
7	33,264	32,893	32,200	-1,064	6.5	-1,037
8	69,288	66,273	51,067	-18,221	1	-2,733
9	86,095	84,289	77,937	-8,158	1	-1,224
10	36,298	35,118	30,351	-5,947	2.5	-2,230

Notes
1) Farm resource income includes farm profit, investment income from surplus working capital, income from off-farm employment and the SFP.
2) Assumes the LFA beef and sheep farm sector contains approximately 15,000 farms.

4.4 Determining LFACA payment rates to avoid land abandonment

Assuming the overall objective of an LFACA Scheme is to ensure continuation of sustainable agricultural activity in those areas that contain the most valuable habitats and landscapes, the behaviour that is to be encouraged is the undertaking of agricultural activity where that activity would not otherwise be viable. The models were used to determine the level of payment required to ensure that agricultural activity takes place and that mixed grazing (which delivers the greatest biodiversity benefits) also occurs on beef and sheep farms in the LFAs in Northern Ireland. The opportunity cost of farm family labour and capital must be considered because farm families will only actively farm LFA land, rather than abandon it, when this farming activity is able to give a better return for all the resources involved than the returns that these resources would earn in alternative uses. The models must also take account of the availability of these farm family resources and how these resources are best allocated for the whole farm business. Therefore, the analysis should take a whole farm approach and not just examine the problem from the perspective of one enterprise or resource.

In this model simulation it is assumed that land can largely be abandoned and that SFP can still be claimed. If necessary, overgrown heather, gorse and rushes could be controlled as appropriate by burning, cutting and chemically (i.e. weed wiping) – therefore, avoiding the use of grazing livestock. However, it is assumed that the farmer prefers to have his own land farmed to help maintain its capital value. The model assumes that he satisfies this preference by farming his own land with cattle and sheep. It is also assumed that the fixed overhead costs of farming have been covered by the farming activities undertaken on owned land. With beef and sheep production currently unprofitable in its own right, these fixed overhead costs must therefore be covered by the farmer's SFP (the largest component being the historic element) which is assumed to be consolidated on owned land. The farmer is therefore cross subsidising their loss making farming activities in order to protect the capital value of their own land.

Similarly, a land owner that maintains SFP entitlements on their land, will prefer to have their land farmed in order to protect its capital value. That is, rather than abandoning their land they will prefer to lease it out in conacre to be farmed by another farmer. Again this is only feasible, however, if it is profitable for the other farmer to farm this land. Therefore, the land owner is using a proportion of their SFP entitlements to cover the costs of letting land out in conacre. These costs will include livestock fencing, water supply, auctioneers fees etc. Given that the land owner does not have to farm his land in order to claim his SFP, they are therefore cross subsidising their conacre renting activities in order to protect the capital value of their land.

The likely reduction in the capital value of land resulting from land abandonment is likely to be much less on SDA land than that on DA or Non-LFA land. Moreover, DA and Non-LFA land is more likely to have value in the conacre market from, for example, dairy and arable farmers. All this would suggest that land abandonment is much more likely in the SDA.

A modified version of the model was employed in the analysis of land abandonment. The following assumptions were made in this particular modelling simulation: (1) Labour is hired out at £9.07 per hour - this is the median gross hourly earnings for all workers in NI in 2007 (i.e. male, female, part-time and full-time); (2) land that is abandoned can be used to claim SFP; (3) the farmer does not participate in the CMS; (4) an annual average U3 steer price of £2.00 per kg is assumed; (5) an annual average U3 lamb and hogget price of £2.50 per kg is assumed; (6) rough grazing can be rented in conacre at zero £'s per ha (this land can only be used for beef and sheep production); (7) working capital can be invested off-farm at an interest rate of 3%; (8) to obtain a Mixed Grazing Bonus at least 25% of eligible Livestock Units must be eligible cattle and at least 25% of eligible Livestock Units must be eligible sheep; (9) in the mixed grazing simulation it is assumed that overheads would increase by 10% because of the increased costs incurred when both cattle and sheep enterprises have to be maintained on the farm; and (10) pasture management systems involving zero inputs of phosphate, potash and/or lime are included in the model. Finally, as this version of the model contained convex non-linear terms, it was solved within the General Algebraic Modelling System (GAMS) using the Branch-And-Reduce Optimisation Navigator (BARON). While traditional mathematical programming algorithms are guaranteed to solve only under rather restricted mathematical conditions, BARON is guaranteed to provide optimal solutions under fairly general mathematical assumptions.

Table 9 indicates that under these assumptions that a flat rate payment of £39/ha (weighted average) is the break even point above which agricultural activity will be maintained across most farm land. This payment ranges from £27/ha to £65/ha across the ten representative models. Mixed grazing has been shown significantly to enhance biodiversity benefits and the modelling exercise has demonstrated that a weighted average payment rate of £49/ha (range £36/ha - £70/ha) is required to ensure mixed grazing is practised.

5. Summary of main findings

Interdisciplinary research work involving both agricultural scientists and economists is challenging; nevertheless, it is increasingly important given public concerns regarding the impact of agricultural technology on food security and the natural environment. The business models discussed in this paper represent such interdisciplinary work, in that data generated by agricultural scientists on the physical relationships associated with various beef and sheep production technologies have been incorporated into profit maximising whole-farm bio-economic models to identify optimal farm business strategies. These bio-economic farm business models aim to accurately and comprehensively model the two-way interaction between physical and economic variables.

Consideration was given to the full range of cattle and sheep enterprises that are feasible within the LFA when constructing the farm business models employed in this study. A key feature of the models is their ability to examine what profit maximising farm businesses should do in market and policy settings that are out-with past experience. This indicates the direction that the sector would take if a particular combination of market and policy conditions were to be maintained in the long-run. The models are useful, therefore, in helping to develop industry strategy. This is evidenced, for example, by the fact that the model's findings continue to inform the work of the Northern Ireland Red Meat Industry Task Force.

Table 8 **Enterprise Mix under various LFACA assumptions**

Model	LFACA Options [1]	Suckler Cows (hd)	Other Cattle (hd)	Breeding Ewes (hd)	Other Sheep (hd)
1	LFACA - CB	2	27	-	-
	LFACA - no CB	2	27	-	-
	LFACA - off	-	29	3	1
2	LFACA - CB	1	41	13	3
	LFACA - no CB	1	41	13	3
	LFACA - off	-	48	4	1
3	LFACA - CB	2	51	35	9
	LFACA - no CB	1	51	40	10
	LFACA - off	-	60	23	6
4	LFACA - CB	6	72	-	-
	LFACA - no CB	6	72	-	-
	LFACA - off	-	79	10	2
5	LFACA - CB	23	316	-	-
	LFACA - no CB	23	316	-	-
	LFACA - off	-	349	21	5
6	LFACA - CB	6	151	141	35
	LFACA - no CB	-	151	166	42
	LFACA - off	-	151	166	42
7	LFACA - CB	8	112	-	-
	LFACA - no CB	8	112	-	-
	LFACA - off	-	122	8	2
8	LFACA - CB	17	100	371	93
	LFACA - no CB	-	91	447	112
	LFACA - off	-	101	432	108
9	LFACA - CB	7	180	162	40
	LFACA - no CB	3	174	190	47
	LFACA - off	-	220	106	26
10	LFACA - CB	5	74	113	28
	LFACA - no CB	-	68	137	34
	LFACA - off	-	84	98	25

Note: 1. CB = cattle bonus

Table 9. Breakeven LFACA payments across the ten models to avoid land abandonment and ensure mixed grazing occurs

	Large*			Medium*			Small*			
Model	**8**	**9**	**5**	**6**	**10**	**7**	**3**	**4**	**2**	**1**
Owned land (ha)	420	202	163	99	128	53	44	39	21	14
%SDA farmed	85	85	73	80	96	44	84	54	59	50
% Moorland/rough grazing	81	60	22	15	75	16	49	26	18	26
% of population	1	1	1	3	3	7	10	22	26	28
Standard LFACA payment (£/ha)	44	27	28	34	33	28	28	28	28	65
Potential mixed grazing supplement (£/ha)	4	9	9	8	9	10	13	11	14	5

* size classification used here is not aligned to those used for EU farm typology

The farm models indicate that, under current market and policy conditions, a dairy-based beef system is likely to be the most profitable beef enterprise on LFA beef and sheep farms. However, depending on land quality and livestock housing resources, and the market and policy environment (e.g. the LFACA scheme), suckler-based beef systems can also feature, along with dairy-based beef systems, in the profit maximising enterprise mix on these farms. Compared to suckler beef production, the dairy bred beef calf has the cost advantages of essentially being a by-product of milk production. However, growth potential and carcass quality are likely to be significantly better in suckler beef systems. The opportunity to gain premiums under various Aberdeen Angus marketing schemes enables Aberdeen Angus systems to compete better in terms of profitability with conventional systems involving continental bred cattle.

The results suggest that the optimal system for sheep in the LFAs involves the mating of hardy hill ewes (i.e. Scottish Blackface) with Leicester rams primarily to produce replacement crossbred ewe lambs for the lowland flocks. This is consistent with the three-stage stratified sheep systems traditionally operated in Northern Ireland. However, if the demand for these crossbred ewe lambs from lowland farms declines, then the viability of these stratified sheep systems is less secure. In that case, there are various arguments for and against the other systems included in the model. The models would suggest that mating the Blackface ewe with a terminal sire (i.e. a simple two-stage stratified system) is marginally better than keeping lowland type crossbred ewes and mating them with a terminal sire. Of course, for the various Blackface systems to be sustainable, a proportion of Blackface ewes must be bred to a Blackface ram, being either produced on that farm or purchased from another farm. In terms of finishing systems for store lambs, the most profitable system involves grazed grass and concentrates.

In general, beef production appears to have some advantages over sheep production where farm families are attempting to maximise total income from available farm resources. Compared to sheep systems, beef systems are generally more capital intensive, but less labour intensive. Therefore, depending on relative prices and resource availabilities, it is often better to replace sheep with cattle and employ the released labour off-farm, than to replace cattle with sheep and invest the released capital off-farm.

The models were specifically employed to identify the levels of LFA payments, and associated management restrictions, that are required to make it financially attractive for farmers to manage LFA land in a way that delivers beneficial environmental outcomes. The models' results highlight several important implications for the future development of the LFACA Scheme. Namely, (1) the LFACA scheme does change farmer behaviour; (2) in the absence of the LFACA, the suckler cow enterprise ceases to be optimal (although, by a narrow margin in some cases) and is eliminated on farms seeking to maximise their incomes; (3) a cattle bonus can be effective in promoting mixed grazing that may not otherwise occur, particularly on poorer quality land; and (4) the influence of the LFACA on farming incomes and behaviour (including land abandonment) is likely to be more marked in the Severely Disadvantaged Area.

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