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Identifying Financially Versatile Milk Production Systems

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Abstract

The European dairy industry faces an increasingly uncertain world. There is uncertainty about, for example, subsidy payment levels and compliance conditions, global competition, price variability, consumer demand, carbon footprints, water quality, animal welfare, food safety, and the environment. Farmers can reduce their exposure to these uncertainties by adopting production systems that are financially versatile over a wide range of possible circumstances. In this research project we develop a profit maximizing whole-farm model and employ it to identify financially optimal milk production systems for a typical Northern Ireland farm under varying market, policy and farm family conditions. The systems assessed range from lower yielding New Zealand type systems based on grazed grass to very high yielding North American type systems based on concentrates and conserved forage. The model also incorporates a disaggregated specification of time use within farm households and links intra-household human resource allocation to the process of agricultural technology adoption. Model results indicate that the optimal dairy system for a typical Northern Ireland farm is one that is somewhere between the extremes of those systems adopted in North America and New Zealand. Moderate input-moderate output milk production systems (i.e. 7,000 to 8,000 litre yields) are shown to be financially robust over a wide range of milk prices, concentrate prices, fertilizer prices, and farm family conditions. Low input-low output (New Zealand style) and high input-high output (North American style) systems are found to be less financially versatile.

Keywords: farm modelling, production systems.

JEL classification: Q12 and Q16.

1. INTRODUCTION

The European dairy industry faces an increasingly uncertain world. For example, there is uncertainty about subsidy payment levels and compliance conditions, global competition, price variability, consumer demand, carbon footprints, water quality, biodiversity, landscapes, animal welfare, and food safety, etc. The future is uncertain because it cannot be reliably predicted; therefore the industry must adopt production systems that will be financially robust over a wide range of possible circumstances. Adding to the uncertainty is a lack of consensus regarding the specific characteristics of these sustainable production systems. In this interdisciplinary research project we developed a profit maximizing whole-farm model and employ it to identify robust milk production systems for Northern Ireland under varying market, policy and farm family conditions. This work illustrates how profit maximizing whole-farm models can play a decision support role in helping farmers, agricultural researchers, agribusiness advisers and agricultural policy makers to identify economically sustainable agricultural production systems.

2. DESCRIPTION OF PRODUCTION SYSTEMS EVALUATED

The model currently contains seventeen dairy system options. These systems range from 5,000 to 10,000 litre annual yields, including both spring, autumn and non-seasonal calving options, and systems with winter rations based on grass silage only or both grass and maize silage. Milk supply pattern and quality are assumed to vary with calving date and diet. The dairy systems outlined in this paper aim to represent the average input-output parameters for a broad range of Northern Ireland milk production systems. There are six seasonal grass silage systems (i.e. where grass silage is the only winter forage used), namely, three spring-calving systems with average milk production per cow of 5,000, 6,000 and 7,000 litres (i.e. S5, S6, and S7), and three autumn-calving systems with 6,000, 7,000 and 8,000 litre yields (i.e. A6, A7, and A8). There are also three seasonal autumn calving systems that involve mixed forage diets (grass and maize silage) during the winter with 6,000, 7,000, and 8,000 litre yields (i.e. AM6, AM7 and AM8). Finally, there are eight non-seasonal calving confinement systems, four of these based on grass silage as the only forage with 7,000, 8,000, 9,000, and 10,000 litre yields (NH7, NH8, NH9 and NH10), and four involving mixed forages (grass plus maize silage) with again 7,000, 8,000, 9,000, and 10,000 litre yields (i.e. NHM7, NHM8, NHM9, and NHM10). Inputs of silage, grazing and concentrates are calculated for each of these seventeen model systems. Typical Northern Ireland conditions are assumed for grass and maize silage quality, grazing management, and genetic merit of cows. Standard lactation curves for Northern Ireland dairy cows are used (Lennox, 1992) with average daily milk yields calculated for each month. Cows in the autumn-calving systems are assumed to calve on 15 November, have a 305-day lactation, go to grass on 15 April, are dried off on 15 September and are housed on 15 October. Cows in the spring-calving systems are assumed to calve on 15 March, have a 305 day lactation, go to grass on 15 April, are housed on 15 October and are dried off in mid January. It is assumed that cows in the non-seasonal confinement systems are housed for most of the time with only limited use of grazing. Grazed grass is only utilized by those cows whose late lactation and dry period coincides with the 15 April to 15 October grazing season.

The cows are assumed to average 575kg live-weight in the 5,000 and 6,000 litre systems, 600kg live-weight in the 7,000 and 8,000 litre systems, and 625kg live-weight in the 9,000 and 10,000 litre systems. In the seasonal calving systems, conception is assumed to take place 85 days into lactation, with a gestation length of 280 days and calving interval of 365 days. Calving interval is a less critical factor in the high yielding non-seasonal calving systems and may extend to around 400 days. Annual replacement rates are assumed to be 23% for the 5,000 litre system, 26% for the 6,000 litre systems, 25% for the 7,000 and 8,000 litre systems, 26% for the

9,000 litre systems, and 27% for the 10,000 litre systems. Culling rates are assumed to be 4% below replacement rates.

2.1. Concentrates fed per Cow

Using a combined FBS data file for the six year timeframe 2003-'04 – 2008-'09, we tested a number of different regression models aimed at exploring the relationship between average yield per cow and the level of concentrates fed per cow (kgs fresh weight). A linear regression model represented the most statistically significant relationship between average yield and concentrates fed per cow:

Average Yield per Cow (ltrs) = 3,537.84 + 1.419 (Concentrates fed per Cow (kgs))

Both estimated coefficients are highly significant, ($P<0.01$). R-squared for the equation is a rather modest 0.52, suggesting that there are a number of other factors, in addition to level of concentrates fed, which effect litres of milk produced per cow. The estimated equation was employed to calculate the level of concentrates fed per cow for each of the systems. Because the equation was estimated using survey level data it was necessary to employ the analysis contained in Anderson and Mayne (2006) to calculated concentrate intakes that are differentiated by seasonal or non-seasonal calving, summer grazing or confinement, and grass silage or grass-maize silage diets.

2.2. Labour Requirements

A linear multiple regression model was employed to investigate the relationship between '*dairy herd labour*' and two explanatory variables '*average yield per cow - litres*' and the '*average number of dairy cows in herd.* The multiple regression model was estimated using FBS data over a six year timeframe from 2003-04 to 2008-09. The results for the model are as follows:

Dairy Herd Labour (hrs) = 1,018.95 + 0.071 (Average Yield per Cow (ltrs)) + 21.187 (Average Number of Dairy Cows (hd))

The constant, yield and herd size coefficients are significant at the 0.01, 0.05, and 0.01 levels respectively. R-squared for the equation is 0.65 indicating that the model is a reasonably good fit for the data. The estimated equation was used to calculate the level of labour required per cow in each the dairy systems.

2.3. Overhead Costs

Using FBS data for the year 2008-09, we estimated a linear multiple regression model that quantified the relationship between 'dairy herd overhead costs' with 'average number of dairy cows in herd' and 'average yield'. The following model was chosen as it represented the best option in terms of economic consistency, model tractability and statistical significance. The estimated equation is as follows:

Dairy Overhead Costs (£) = -13,912.08 + 369.39 (Number of Dairy Cows (hd)) + 2.39 (Average Yield per Cow (ltrs))

The constant, herd size and yield coefficients are significant at the 0.01, 0.01, and 0.05 levels respectively. R-squared for the equation is 0.85 indicating that the model is a very good fit for the data. The estimated equation was used to calculate the level of overhead costs per cow incurred in operating each of the dairy systems.

2.4. Forage Intakes

Total dry matter intakes of grass silage, maize silage and grazed grass are based on the dairy production systems reported in Anderson and Mayne (2006). The feed inputs required to support target daily milk yields for each system during the housed period were estimated in Anderson and Mayne (2006) using the Feed into Milk (FiM) model (Offer *et al.* 2002). Anderson and Mayne (2006) also assumed typical grazing management, which is taken to be a paddock grazing system with some supplementation with a grazing concentrate as necessary. Grazed grass utilisation was assumed to be 75%.

2.5. Protein and Butterfat Percentages for Model Systems

The average butterfat and protein percentages for the different model systems are based on estimates contained in Anderson and Mayne (2006). Both fat and protein percentages are assumed to vary with calving season, but only protein is assumed to vary with yield.

2.6. Costs of Feed Inputs

Concentrate and fertilizer prices, as well as the costs of producing silage and grazing, were taken from Farm Business Data (DARD). In order to mitigate for the quite large variation in absolute and relative prices resulting from recent market volatility for these key inputs, the baseline model was calibrated using five year average prices for the various types of concentrates and fertilizer used.

2.7. Leasing of Resources

It is assumed that additional land can be rented in the form of conacre. Additional capital can be borrowed on a Current Account and also on a Term Loan over a ten year period (i.e. where all capital and interest is fully paid back at the end of ten years). Milk quota leasing price is assumed to be negligible. Finally, it is also assumed that extra labour can be hired in.

2.8. Alternative Enterprises

Four alternative enterprises are included, namely, dairy heifer rearing, 24 month beef, lowland breeding ewes and spring barley. The revenues, variable costs, overhead costs and capital requirements associated with the alternative enterprises are taken from Farm Business Data (DARD). Labour requirements for alternative enterprises are from Nix (2001). The dairy heifer rearing enterprise, although grouped with the alternative enterprises, may not be considered as a true alternative enterprise, as there is no option for selling the reared heifers or buying in replacement heifers. Due to assumed differences in animal size - silage, grazing and concentrate requirements for heifers from the 5,000 and 6,000 litre systems are assumed to be lower than for heifers from the 7,000 and 8,000 litre systems, which in turn are assumed to be lower than for heifers from the 9,000 and 10,000 litre systems.

3. MILK PURCHASING CONTRACTS

The basic milk contract incorporated into the linear programming model employed in this study has four main parameters: (1) average annual base price, (2) seasonal base price variation, (3) butterfat bonus / penalty, and (4) protein bonus / penalty. It is assumed that other elements of the milk purchasing contract, such as hygienic quality, presence of added water or transport charges, are all system neutral.

3.1. Average Annual Base Price

The average annual base price sets the basic level of milk prices received by milk producers in any given year. The level at which this annual base is set will have a very significant impact on milk producer profits, the quantity of milk produced by each individual producer, and the number of producers agreeing to supply any individual processor. In order to dampen the change in absolute and relative milk prices resulting from significant milk market volatility in recent years, the baseline model was calibrated using a five year average milk price (i.e. a baseline milk price of 20ppl - the 5 year average NI milk price over years 2005-09).

3.2. Seasonal Price Variation

Milk buyers vary monthly milk prices over the year both in response to the milk supply/demand situation, and to influence farmer decisions on calving profile and hence volume of milk supplied per month. The model incorporates this monthly milk price variation as a percentage deviation from the average yearly milk price. For most model simulations (unless otherwise stated) the seasonal price variation is assumed to follow the observed variation in monthly milk prices over the five years (2005 – 2009). Over this period the monthly price variation, expressed as a percentage deviation from the average yearly price, on average ranged from the lowest month (May) at minus 9.7% to the highest month (November) at plus 15.9%. Finally, based on results from Lennox (1992), the model calculates (at matrix generator stage) the monthly milk supply assumed in each system.

3.3. Butterfat Bonus / Penalty

In the basic contract incorporated in the model the bonus / penalty for butterfat is 0.018 pence per 0.01% deviation from a standard base quality of 4.00% butterfat. Therefore, milk produced in any given month with a butterfat percentage less than 4.00% will have a penalty deducted from the relevant monthly base price, while milk with a butterfat percentage more than 4.00% will have a bonus added to the relevant monthly base price. Again, utilizing results from Lennox (1992), the model calculates (at matrix generator stage) the monthly butterfat percentage of milk in each system.

3.4. Protein Bonus / Penalty

In the basic contract incorporated in the model the bonus/penalty for protein is 0.032 pence per 0.01% deviation from a standard base quality of 3.18% protein. Again, milk produced in any given month with a protein % less than 3.18% will have a penalty deducted from the relevant monthly base price, while milk with a protein % more than 3.18% will have a bonus added to the relevant monthly base price. There are no payments or deductions for lactose. Results from Lennox (1992) were again utilized by the model to calculate (at matrix generator stage) the monthly protein percentage of milk in each system.

4. DECISION MAKING AND FARM HOUSEHOLDS

Farm-level micro-analysis has traditionally focused on the farm business as the main unit of analysis. However with increased interest in modelling household-decision making in the wider economic literature, there has also been an increased interest in the decision-making process within family farm households and how the main household decision makers, namely the operator and spouse (if applicable) influence the economic well-being of the household and how those decisions ultimately impact on farm performance. Within the context of farm households, the decision process regarding how resources are allocated has an important bearing upon choices in terms of family consumption versus farm investment; time devoted to on and off-farm employment activities as well as leisure; gender–based division of labour within the household; human capital formation and education decisions; and finally, farm production response to market and policy based incentives. Farm households are a diverse group, decisions about resource allocation, particularly labour and time-use, will be based on individual farm and farm 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 on-farm and therefore allow 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 decision by farm households to allocate labour to farm and off-farm activities reflects the returns for the alternative use of that labour. 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. 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.

Farm business decisions regarding technology adoption and production systems are increasingly being influenced by labour availability within the farm household, (Fernandez-Cornejo et al. 2007). 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.

Incorporating the dimension of 'time–use' into a profit maximizing farm household model allows an analysis of the robustness of a range of dairying systems; robustness not only from the perspective of farm profitability but also from the perspective of optimising household labour allocation decisions. Rather than examining the farm business or farm household in isolation, this integrated approach 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.

4.1. 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. 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, 233 were dairy farms.

4.2. Selection of Dairy Farm Household Typologies

We identified 'life cycle' phases within the household, in order to capture the key transitions in the life cycle of the typical household and to demonstrate the demands that caring for children place on allocation of time, for both the farm operator and spouse. Four household typologies were identified based on the presence and age of children within the dairy farm household. The typologies are as follows: (1) *Younger Households* – these households have children under the age of 10 years present but may also have older children as well; (2) *Older Households* – these have children between the ages of 10 and 15 years present and do not have any children under 10 years of age present; (3) *Households with no children under 16 years* - these households do not have any children under the age of 16 years living in the household but have more than two family members living in the household; and (4) *Farm Operator-Spouse only Households* - these households consist only of the Farm Operator and his/her Spouse. Using these household typologies, we analysed dairy farm operators and their spouses' allocation of time across four main activities: on farm labour, off farm labour (employment and self employment), caring and home production activities.

5. AVAILABILITY OF RESOURCES

Estimates of owned land, working capital and milk quota for dairy herds of between 70 and 80 cows (average herd-size 75 cows) were taken from the Farm Business Survey 2008-09 (DARD). FBS data includes 12 farms in this size bracket. The average land area owned by farmers with 75 cow dairy herds is 39.7 hectares. A total of £57,681 of own capital is assumed to be available to finance livestock, working capital, and machinery, with any additional capital requirements for these items needing to be borrowed. Average milk quota owned for this sample of farms is 378,052 litres. Dairy cow housing is not specifically recorded in FBS, but a maximum of 80 cow places has been assumed. Other cattle housing includes housing for heifer rearing and 24 month beef production, with a maximum of 40 places assumed in the model. Each other cattle housing place consists of housing for one animal between 1 – 12 months and one animal between 13 – 24 months, with these cattle places equally suitable for either 24 month beef production or heifer rearing. The total supply of labour by farmer and spouse was estimated from the farm household survey discussed in section 4.2 above. This total labour supply relates to all time spent by the farmer and spouse in farm work, off-farm employment (including self employment off-farm), childcare, caring for others (perhaps elderly, sick or disabled individuals) and home production activities.

6. MODEL RESULTS

The coefficients discussed in Sections 2, 3, 4 and 5 were incorporated into a linear programming model. The model was solved using the GAMS/CONOPT 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 CONOPT is used in this case. In these model simulations it is assumed that the butterfat bonus/penalty equals 0.018p per 0.01% deviation from a standard base quality of 4.00% butterfat; that the protein bonus/penalty equals 0.032p per 0.01% deviation from a standard base quality of 3.18% protein; and that the seasonal adjustment in base prices follows the historic average observed over the five years (2005 – 2009).

6.1. The Optimal System as Milk Prices Change

Table 1 summarizes the results of model simulations involving changes in milk price. These are annual base price changes, with monthly milk prices varying throughout the year according to the seasonal structure of monthly base prices being assumed. The model results reported in Table 1 show the optimal milk production system when the average annual base price is 16ppl, 20ppl and 24ppl.

In Table 1 it is clear that with annual average milk prices ranging from 16 ppl to 24 ppl that the optimal milk production system is consistently shown to be a moderate input-moderate output system. That is, either a spring calving herd, yielding an average 7,000 litres per cow (i.e. S7), or an autumn calving herd, fed grass and maize silage, yielding an average 8,000 litres per cow (i.e. AM8). Annual farm income, excluding all subsidies and off-farm employment income, ranges from £22,584 to £68,664 as the milk price increases from 16 to 24 pence per litre.

Table 1 Annual Milk Price Simulation[1]

	Annual Milk Price (pence per litre)		
	16	20	24
Optimal Dairy System	S7	AM8	AM8
Dairy Cows (hd)	79	78	80
Dairy Heifer (hd)	40	39	40
Farm Income[1] (£)	22,584	44,200	68664

Note: 1. Excluding all subsidies and off-farm employment income

6.2. Relative Profitability of the Alternative Systems at 16, 20 and 24 ppl

Table 2 illustrates the relative profitability of the ten best systems at milk prices ranging from 16p/litre to 24p/litre. The values in brackets represent the increase in profit per cow (£/cow) required for that system to be equal in profitability with the optimum system. Two points are worthy of note. First, although spring systems are shown to be best when milk prices are low, the equivalent autumn calving systems are nevertheless not that far from the optimum even at these low prices. Second, as expected the higher yield systems, regardless of calving pattern, perform much better than lower yield systems when milk prices are high.

6.3. Concentrate Prices

Table 3 shows the effect of changes in concentrate prices on the optimal system. From Table 3 it is clear that, even when concentrate prices vary by plus or minus 20%, the optimal milk production system remains a moderate input-moderate output system. That is, either a spring calving herd yielding an average 7,000 litres per cow (i.e. S7), or an autumn calving herd, fed grass and maize silage, and yielding an average 8,000 litres per cow (i.e. AM8). However, although the optimal systems remain relatively stable as concentrate prices vary, in contrast, farm incomes change significantly.

Table 2 Relative profitability of systems at various milk prices

Rank Order at Milk Price of 16p/litre (profit increase required to be optimum)	Rank Order at Milk Price of 20p/litre (profit increase required to be optimum)	Rank Order at Milk Price of 24p/litre (profit increase required to be optimum)
1. S7 (optimal system)	1. AM8 (optimal system)	1. AM8 (optimal system)
2. S6 (-£9/cow)	2. S7 (-£1/cow)	2. NHM10 (-£1/cow)
3. S5 (-£14/cow)	3. A8 (-£14/cow)	3. A8 (-£14/cow)
4. AM8 (-£31/cow)	4. AM7 (-£39/cow)	4. NH10 (-£30/cow)
5. AM7 (-£38/cow)	5. S6 (-£40/cow)	5. S7 (-£36/cow)
6. AM6 (-£41/cow)	6. A7 (-£51/cow)	6. NHM9 (-£69/cow)
7. A8 (-£46/cow)	7. NHM10 (-£70/cow)	7. AM7 (-£74/cow)
8. A7 (-£51/cow)	8. AM6 (-£72/cow)	8. A7 (-£87/cow)
9. A6 (-£51/cow)	9. S5 (-£76/cow)	9. NH9 (-£97/cow)
10. NHM8 (-£144/cow)	10. A6 (-£82/cow)	10. S6 (-£110/cow)

Table 3 Effect of changes in concentrate price on optimum system (annual milk price @ 20p/litre)

Concentrate Prices	Optimum System	Dairy Cows	Dairy Heifers	Farm Income[1]
- 20%	AM8	80	40	53,867
Baseline	AM8	78	39	44,200
+ 20 %	S7	79	40	36,916

Note: 1. Excluding all subsidies and off-farm employment income

6.4. Fertilizer Prices

Table 4 shows the effect of changes in fertilizer prices on the optimal system. Although fertilizer prices are allowed to vary by plus or minus 20%, the optimal milk production system is a moderate input-moderate output system. That is, either a spring calving herd, yielding an average 7,000 litres per cow (i.e. S7), or an autumn calving herd, fed grass and maize silage, yielding an average 8,000 litres per cow (i.e. AM8). Farm incomes also remain relatively stable as fertilizer prices vary.

Table 4 Effect of changes in fertilizer prices on optimum systems (annual milk price @ 20p/litre)

Concentrate Prices	Optimum System	Dairy Cows	Dairy Heifers	Farm Income[1]
- 20%	S7	79	40	45,657
Baseline	AM8	78	39	44,200
+ 20 %	AM8	78	39	42,897

Note: 1. Excluding all subsidies and off-farm employment income

6.5. Farm Family Characteristics

The results incorporating operator and spouse hours to paid and unpaid employment by identified ‘life cycle’ phases (discussed in section 4.2) as defined by the presence and ages of children within a household, are presented in Table 5. The results compare the overall average for farm households against those households with younger children. When it is assumed that the household has young family members, which increases caring responsibilities, it is found that the presence of young family members have no impact on the optimal milk production system, which remains as a *moderate input-moderate output system*. Most of the additional caring responsibilities are undertaken unpaid by the spouse, which along with her contribution from off-farm employment helps to maintain overall farm household income at a level broadly similar to that of the average household.

Table 5 Changes in Farm Family Characteristics[1]

Optimal Dairy System	Average Household	Young Family Household
Dairy Cows (hd)	78 (AM8[2])	80 (AM8[2])
Dairy Heifer (hd)	39	40
24 month Beef (hd)	-	18
Farmer – farm (hrs)	3,786	4,096
Farmer – home production (hrs)	104	81
Farmer – caring (hrs)	425	811
Spouse – home production (hrs)	1,634	1,616
Spouse – caring (hrs)	1,344	3,294
Spouse – off-farm employment (hrs)	956	981
Other family - off-farm employment (hrs)	455	-
Farm Income[3] (£)	44,200	45,082
Farm and Off-farm Income[4] (£)	56,899	53,911

1. Assumes milk price is 20 ppl with all other model parameters at baseline values.
2. AM8 = autumn-calving system with grass and maize silage and 8,000 lt. yields.
3. Excluding all subsidies and off-farm employment income
4. Excluding all subsidies

Table 6, presents the results for model scenarios where the off-farm wage rate for the spouse in households with younger children is assumed to vary. When the off-farm wage rate for the spouse is allowed to vary by plus or minus 20% from the assumed baseline wage rate, with all other prices remaining at baseline levels, the optimal milk production system is shown to remain as a *moderate input-moderate output system*. Increasing or decreasing the off-farm wage for the spouse by these magnitudes has no effect on the how both the spouse and farm operator allocate their time to farm and off farm activities. The household time commitment to caring and home production also remains unchanged. However, total overall household income varies by a relatively modest 3.3% with these plus or minus 20% variations in the off-farm wage rate earned by the spouse.

Table 6 Off-farm Wage Changes for Spouse in Young Family Household[1]

Optimal Dairy System	Young Family Household with -20% in spouse off-farm wage[3]	Young Family Household with Baseline spouse off-farm wage	Young Family Household with +20% in spouse off-farm wage[4]
Dairy Cows (hd)	80 AM8[2]	80 AM8[2]	80 AM8[2]
Dairy Heifer (hd)	40	40	40
24 month Beef (hd)	18	18	18
Farmer – farm (hrs)	4,096	4,096	4,096
Farmer – home production (hrs)	81	81	81
Farmer – caring (hrs)	811	811	811
Spouse – home production (hrs)	1,616	1,616	1,616
Spouse – caring (hrs)	3,294	3,294	3,294
Spouse – off-farm employment (hrs)	981	981	981
Farm Income[5] (£)	45,082	45,082	45,082
Farm and Off-farm Income[6] (£)	52,145	53,911	55,677

1. Assumes milk price is 20 ppl and all other model parameters at baseline values.
2. AM8 = autumn-calving system with grass and maize silage and 8,000 lt. yields.
3. Spouse off-farm wage is assumed to be reduced by 20% from the baseline value (i.e. reduced from £9.00/hr to £7.20/hr).
4. Spouse off-farm wage is assumed to be increased by 20% from the baseline value. (i.e. increased from £9.00/hr to £10.80/hr)
5. Excluding all subsidies and off-farm employment income
6. Excluding all subsidies.

7. CONCLUSION

The results from this research indicate that the optimal dairy system for a typical Northern Ireland dairy farm is one that is somewhere between the extremes of those systems adopted in the US and NZ. Moderate input-moderate output milk production systems *(i.e. 7,000 to 8,000 litre yields)* are shown to be financially versatile over a wide range of milk prices, concentrate prices, fertiliser prices, and farm family characteristics. Low input-low output (NZ style) and high input-high output (US style) systems are found to be rather less versatile. Low input-low output systems perform better financially, relative to higher input-output systems, when milk prices are low, concentrate prices are high, and fertilizer prices are low. In contrast, high input-high output systems perform better financially, relative to lower input-output systems, when milk prices are high, concentrate prices are low, and fertilizer prices are high. Nevertheless, regardless of whether the prevailing economic conditions for milk production are assumed to be very favourable or very challenging, moderate input-moderate output systems are found to be either optimal, or close to optimal.

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