The economic viability of biomass crops versus conventional agricultural systems and its potential impact on farm incomes in Ireland

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Paper prepared for presentation at the 107th EAAE Seminar *"Modelling of Agricultural and Rural Development Policies"*. Sevilla, Spain, January 29th -February 1st, 2008

Abstract:

Ireland is currently importing 90 percent of its energy. The burning of domestically produced non-renewable peat provides 4.9 percent of Ireland's total primary energy supply while renewable biomass crops currently account for only 1 percent of the domestically produced energy supply. The Irish government have set a target of 30% of peat (approximately 0.9 million tonnes) used for electricity generation to be replaced by renewable energy crops. This would be equivalent to approximately 0.6 million tonnes of biomass crops or approximately 45,000 hectares of biomass. Direct payments and subsidies accounted for over 100 percent of average family farm income on beef and sheep farms in 2006. Therefore there appears to be significant potential for Irish farmers to replace conventional agricultural enterprises with biomass crops. A probit model was built to identify the socio-economic characteristics of farmers who may be willing to adopt energy crop production. The results from this were used in the construction of a linear programming model to determine the optimal enterprise for each farmer at varying energy prices.

Key words: Willow, Miscanthus, Co-firing, Net present value, Probit, Linear programming.

1. Introduction

Significant increases in world oil, gas and coal prices have recently made fossil-based electricity and heat production substantially more expensive in the Republic of Ireland. These high prices may reflect a new era of higher energy costs exacerbated by limitations in the rate of oil supply and rapidly increasing demand from the growing economies of China and India. Commitments to reduce greenhouse gas emissions made by the Irish government under the Kyoto Protocol as well as the introduction of the E.U Emission Trading Scheme (ETS) in 2005 and the likely increase in future CO_2 permit values will further increase the costs incurred by large scale fossil fuel combustion. At the recent U.N Climate Change Conference in Bali the E.U proposed a reduction on industrial nation's emissions by 25%-40% below 1990 levels by 2020. Alternatives to fossil fuels are essential if Ireland's ability to supply its energy needs is to be maintained. As a result a target of 30% substitution of biomass for peat in the state owned power stations at Edenderry, Lanesboro and Shannonbridge by 2015 has been set by the new Renewable Energy Feed in Tariff (REFIT) scheme. In order to achieve this target, approximately 55,000 hectares of willow or 36,000 hectares of miscanthus need to be planted, representing roughly 0.8% to 1.25% of total agricultural area in Ireland. However, a knowledge gap exists on the extent to which Irish farmers would actually choose to grow energy crops. Hence, this paper is focused on modelling the factors influencing the adoption decision at farm level. The hypothesis that a farmer's reluctance to switch to energy crop production may be as a result of individual and farm specific circumstances is examined. Furthermore, the influence of the price paid per Giga-Joule (GJ) supplied on a farmer's decision to adopt is also analyzed.

The following section describes the data used in the analysis. The initial section of the paper outlines the econometric (probit) model that was developed to analyze the factors affecting a farmer's willingness to grow willow and miscanthus. This section also outlines the energy crop costings model and the linear programming (LP) profit maximising model. The crop costings model was constructed to calculate the returns from willow and miscanthus. The LP model was developed to allow for comparisons between these returns with those of conventional agricultural systems such as dairy, beef, sheep and cereals. The empirical results of these models are then outlined and discussed.

2. Background

Probit has been applied to model farm level decision making by Damisa (2007), Rahji (1998) and Thorne (2007). The results of these papers indicate that the socio-economic characteristics of the farmer influenced the decision they made. The probit methodology was also employed in this paper in order to discover the socio-economic characteristics that affect a farmer's decision to adopt biomass crop production. These characteristics could potentially be used by policy makers and allow for greater accuracy in the type of farmer targeted by future biomass schemes and therefore help boost their effectiveness. The participation rate in existing schemes is much lower than anticipated and if government targets are to met a greater understanding of the target group must be achieved.

The Net Present Value approach used in this paper to calculate the annual returns generated by perennial biomass crops such as willow and miscanthus has been used for a similar purpose by Goor (1999), Heaton (1999), Toivonen (1998), Styles (2006) and Rosenqvist (2004). These papers used sensitivity analysis to identify key parameters with yield level, discount rate, energy price, harvest cycle and subsidies coming through as important. Heaton (1999), Toivonen (1998) and Styles (2006) all used an annual margin they calculated from the crops NPV for comparison with another enterprise. This allowed for an examination of how the crop performed relative to an existing agricultural enterprise and what subsidies would be necessary for the biomass crop to achieve parity. This paper follows this methodology in using the NPV technique to generate an annual value which is then compared to the margins from alternative agricultural enterprises. One major difference between the method used in the papers mentioned above and this paper is the discount rate used. The other papers use a set discount rate (of either 5% or 6%) whereas the discount rate used in this paper follows that suggested by Boehlije and Eidman (1984) and can therefore fluctuate depending on the number of years that the crop is assumed to grow for.

Linear programming has previously been used as a technique for modelling the impact of increased bioenergy production by Treguer (2006), Rozakis (2001), Sourie (2006) and Treguer (2006). These papers have all employed sequential partial equilibrium models to analyze the effect of increased biofuel production at a national level. These models have been used to examine a multitude of policy scenarios, as well as providing the basis for comparisons over the short to medium term with other enterprises. Jones (1982) argues that despite criticism over their normative nature, LP models have particular value in generating a response to situations which are outside the realm of past experience and therefore cannot be modelled by more positive techniques such as econometric models. The recent nature of biomass production in Ireland means that it certainly falls in to this category. The LP method used in this analysis follows a long standing modelling approach used in the Rural Economy Research Centre for policy analysis. The technique has been used for this purpose on numerous occasions such as by Breen and Hennessy (2003), Hennessy (2005) and Thorne (2004).

3. Materials and Methodology

3.1 Data

Two models were constructed using data from the 2006 National Farm Survey [1](NFS) (Teagasc, 2006). Firstly, an econometric model was constructed to examine the factors that affect whether or not a farmer has seriously considered growing energy crops. Secondly, a LP model was constructed in order to determine the price per GJ necessary to achieve the national targets for co-firing of biomass, set out in the government White Paper. The full NFS dataset in 2006 includes 1,159 farms weighted to represent the national farm population of over 113,000 farms. The LP model utilizes cost and price projections from the FAPRI-Ireland baseline model (Binfield et al. 2007) for the period 2007-2017 to simulate farmer behaviour across a 10 year planning horizon. The data used to construct the Energy Crop Costings Model was based on figures received from the Teagasc Crops Research Centre, Oakpark, as well as the FAPRI-Ireland projections. In addition to the individual farm accounting, performance and farmer demographic data collected from the NFS, special studies on individual topics are also conducted. The 'special study' survey conducted in 2006 included a question asking farmers have they 'considered/investigated converting land to energy producing crops?'. While this survey was conducted by the NFS not all respondents for the main survey were participants in the special study, however the survey was re-weighted accordingly. Consequently, the sample size of the dataset used for the probit model was slightly less than that used for the LP model, with 998 individual farms.

The Department of Agriculture, Fisheries and Food (DAFF) supplied data on the farmers who received grants under the Bioenergy Scheme. This allowed for the calculation of the average proportion of the farm that farmer's were willing to dedicate to willow and miscanthus production. It also allowed a similar calculation to be made on a regional basis. Data on the amount of peat burned by the three power stations was gathered from the ESB website. The number of tonnes of willow and miscanthus necessary to replace 30% of the peat burned in these stations was calculated. This figure allowed us to calculate the amount of land required to produce a sufficient amount of biomass, thereby enabling targets to be set for the scheme to be successful.

3.2 Probit Model

The probability that a farmer has considered or investigated converting land to energy producing crops depends on a variety of both economic characteristics such as efficiency and profitability and non-economic characteristics such as farm size, farm age and farm education. For the standard probit model adopted for this research a standard normal distribution was assumed, specified as a log-likelihood equation and estimated using a Maximum Likelihood Estimation (MLE) model. As the co-efficients from this probit model can not be interpreted in the same manner as an OLS (Ordinary Least Squares) regression, it was necessary to compute marginal effects and elasticities to interpret the output from this model.

As part of the special survey farmers were asked to determine their production intentions regarding energy crops: 'Have you considered/investigated converting land to energy producing crops?'. This

[1] The NFS is a member of FADN (Farm Accountancy Data Network).

response variable (DECISION) was recoded into a binary variable which equals zero when a farmer indicated that he/she had not considered or investigated converting land to energy producing crops and one when a farmer indicated that he/she had investigated or considered this option. Just over 92% of respondents reported that they had not considered or investigated the conversion of land to energy producing crops. This response variable was the dependent variable in the probit model estimated. It should be noted that the survey was conducted in the autumn of 2006 and since then information on energy crops has become a lot more prevalent in the popular media. This would, in all likelihood, lead to an increase in the number of farmers willing to explore the possibility of energy crop production. The 2006 farm survey database provides data on individual characteristics which will be used as explanatory variables in the model.

3.3 Energy crop costings model and LP profit maximising model

An economic spreadsheet model was developed to investigate the financial feasibility of biomass crops. The Microsoft Excel based model detailed cashflow data for both willow and miscanthus and permitted an investigation of model sensitivity to shifts in energy price (per GJ). The model uses FAPRI-Ireland projections of price and cost changes in order to generate the returns from willow and miscanthus as well as conventional agricultural systems over a ten year timeframe. At this point, a linear projection of the trend is used to predict the price and cost changes out to 2027 for miscanthus and 2029 for willow. Output from the model is in the form of Net Present Value (NPV). From this value annualised discounted gross margins were calculated using the annuity tables suggested by Boehlije and Eidman (1984). This value allows for comparison between perennial biomass crops and competing annual farm enterprises.

A LP profiting maximising model was developed to select the optimal farm enterprise for each farmer within the NFS dataset. The LP model allowed the farmer to specialise in the production of the enterprise that earned the highest gross margin subject to a number of constraints. The gross margins from the energy crop costings model were then incorporated in order to examine the number of farmers whose optimal enterprise was biomass crop production. If this was the case then the farmer's optimal solution would be to convert some of their land to the production of willow or miscanthus. The proportion of their farm that each farmer would convert to biomass production was dependent on a number of constraints including whether or not the farmer was in REPS or was receiving a disadvantaged area payment.

The co-efficients from the DAFF dataset were used to calculate the proportion of land that each farmer would convert to biomass crop production. The farmers who answered positively to the question in the 'special survey' were allowed to allocate a greater proportion of their farm to energy crop production as by previously stating an interest they would be among the first to adopt. The farmers who responded negatively were allowed to allocate half the proportion of those in the first scenario. The two groups were then amalgamated in to a single population which allowed all farmers to enter production simultaneously. It is this scenario which the results are based on. If the farmer met the criteria for entry, the area that farm would convert to Biomass production was multiplied by the proportion allocated. This allowed for greater realism in the model as historically farmers who were eligible to begin willow or miscanthus production did not put their entire farm or the entire allowable area into biomass production.

3.4. Assumptions

The following section details the assumptions made relating to respective costs and incomes from both willow and miscanthus. Figures were compiled from a review of the relevant literature and in consultation with the Teagasc Energy Systems Specialist. The constraints on the type of farmer (and farm) that can switch to energy crop production are also included.

Model cost and income assumptions for willow

- A maximum production period of 22 years, 11 harvest cycles
- An interest rate of 5%
- FAPRI-Ireland cost and price projections until 2017; Linear projection of trend thereafter
- A yield level of 8t/DM/ha (for the first harvest) and 10t/DM/ha (for every harvest thereafter)
- An assumed moisture content of 25%
- All machinery and labour costs are included

Model cost and income assumptions for miscanthus

- A maximum production period of 20 years, 19 harvest cycles
- An interest rate of 5%
- FAPRI-Ireland cost and price projections until 2017; Linear projection of trend thereafter
- A yield level of 6t/DM (in year 2), 10t/DM (in year 3 and onwards)
- An assumed moisture content of 20%
- All machinery and labour costs are included

Constraints to adopting willow and miscanthus production

- A good quality soil type is required
- A maximum area of 10 hectares or 25% of farm holdings (whichever is greater) is permitted to be switched to energy crop production for those farmers who receive REPS or Disadvantaged Area payments
- Returns for bioenergy production must be higher than that of the existing farm enterprise in 8 out of 10 years
- Farm holders over the age of 65 were excluded from switching (over the age of 70 for a 7 year project) unless they had an identified successor
- Farmers from all other enterprises were excluded from entering dairy production, as the set up costs were perceived assumed to be prohibitive

The effect of the project lifetime on the price per GJ was calculated by examining the returns for the crop at 7 years and 15 years. There are two reasons behind the decision to examine the price at the 7 year mark. Firstly, the national co-firing targets are to be achieved by 2015. As the REFIT scheme will not begin in earnest until 2008, then the price per GJ necessary to attract a sufficient number of farmers to achieve the national targets by 2015 must be ascertained. Secondly, the establishment grant and top up premium paid to farmers under the current Bioenergy Scheme is subject to a minimum plantation time of 7 years. If the farmer decides to cease production before that point, then they will be required to pay back any grants they received. Due to the disproportionably high set up costs involved in energy crop production and the dis-incentive of having to pay back grants, it is assumed that the minimum length of time that a farmer would engage in energy crop production is 7 years.

The effect of a 15 year project lifetime is also examined. This timeframe was chosen as Power Purchase Agreements (PPA's) are the mechanism by which the REFIT aid will be distributed. Under a PPA the retail supplier of electricity undertakes to purchase all the output from a selected renewable energy plant at contract prices which are agreed by both parties at the commencement of each individual contract. This price is to be fixed for 15 years, irrespective of the open market price. The support is to be spread over a 15 year period so as to minimize the aid intensity and to deliver a business case which will attract investors. The price per GJ offered must be sufficiently high to compensate the electricity supplier (with a PPA) for the opportunity cost arising from the Best New Entrant price decreasing over the life of the programme.

The Bioenergy Scheme currently offers an establishment grant that covers 50 percent of establishment costs to a maximum of €1,450 per hectare. However, based on information provided by the Department of Agriculture, Fisheries and Food it is assumed that this grant will be only offered on 1,600 hectares in 2008 and 5,500 hectares in 2009. In order to achieve the national co-firing targets the area planted would need to be significantly higher than the 7,100 hectares budgeted for by the Bioenergy Scheme in 2008 and 2009. The EU energy crops premium initially offered a premia of €45 per hectare on 2 million hectares of bio-energy crops throughout the EU, however the target area was exceeded leading to oversubscription of this premia and as a result the EU are in the process of revising down the premia to €30 per hectare. Therefore in our model we assume that the establishment grant offered by the Bioenergy scheme in 2008 and 2009 would follow the precedent set by the EU energy crops premium and the budgeted money would be distributed equally among all applicants. As a result the premia offered would be significantly lower than €1,450 (approximately €200 per hectare if 55,000 hectares of willow are to be planted and approximately €300 per hectare if 36,000 hectares of miscanthus are to be planted).

The amount of willow and miscanthus necessary to replace 30% of the peat burned in the three power stations was calculated. From this, the number of hectares required to produce this amount of the crops could be established. This area was used as the estimated area to be planted in order to achieve the targets set out in the scheme.

4. Results

4.1 Probit Results

The marginal effect of each variable on the probability of the adoption decision is presented in Table 1. The model is statistically significant at the 1% level or better, as measured by the likelihood ratio test. The marginal effects show the change in the probability of choice j given a change in x_i. In the case of continuous explanatory variables, the marginal effect relates to a change of one unit in the variable. For the binary explanatory variables, the marginal effect is the difference in probabilities between setting the explanatory variable to one and setting it to zero, given that all other explanatory variables are set at their sample means. Overall, the results in Table 1 suggest that the probability of innovation at farm level is significantly influenced by a number of personal and farm specific characteristics.

The marginal effects of the explanatory variables on the decision to adopt emphasise the importance of certain variables over the others. The existing system of farming is shown to be highly significant in the adoption decision making process. The dummy variable for specialist cropping system shows that existing specialist tillage farms are more likely to consider or investigate the growing of energy crops. This is not surprising given the similarities that exist between the production of cereals and energy crops as well as the machinery, soil type and skills needed. The results show that if the current farm enterprise is cereals, there is a 21.7% greater chance that the farmer has considered energy crop production as an alternative enterprise on his farm.

Table 1: Marginal effects from the probit model
y = Pr (decision) (predict)
= .03197663

variable	dy/dx	Std. Err.	z	P>z
Ag-edu holder*	.0502507	.0137	3.67	0.000
Cereal farmer*	.2168365	.08494	2.55	0.011
Successor*	.1216356	.16568	0.73	0.463
Region3*	-.0165213	.01354	-1.22	0.222
Region4*	.0072461	.02088	0.35	0.729
Region5*	-.0073761	.01987	-0.37	0.710
Region6*	.0222959	.02179	1.02	0.306
Region7*	-.0160084	.01416	-1.13	0.258
Region8*	-.0174129	.01622	-1.07	0.283
High Quality Soil*	.0097738	.01237	0.79	0.429
Area	.0004753	.00031	1.54	0.123
$Area^2$	-2.20e-07	.00000	-0.20	0.844
MktGM/ha	-.0000104	.00002	-0.63	0.527
Age	-.0028129	.00306	-0.92	0.357
Age^2	.0000234	.00003	0.80	0.427
Sfp/ha	.0003804	.00019	2.05	0.040
Sfp/ha^2	-4.65e-07	.00000	-1.94	0.052
Off-farmjob*	-.0070291	.012	-0.59	0.558
REPS*	-.0006892	.011	-0.06	0.950
Drystock*	.0096308	.01667	0.58	0.563

Note: (*) dy/dx is for discrete change of dummy variable from 0 to 1

When the agricultural education level of the farm operator is controlled for in the model, agricultural education appears as a highly significant variable. This supports the hypothesis that farmers with higher levels of agricultural education are more open to new ideas and are more willing to investigate alternative farming systems. A one unit change in the agricultural education variable means that the farm operator with agricultural education is 5% more likely to consider or investigate the growing of energy crops, other things being equal. This variable is statistically significant at the 1% level, further highlighting its importance as a factor in the decision to adopt.

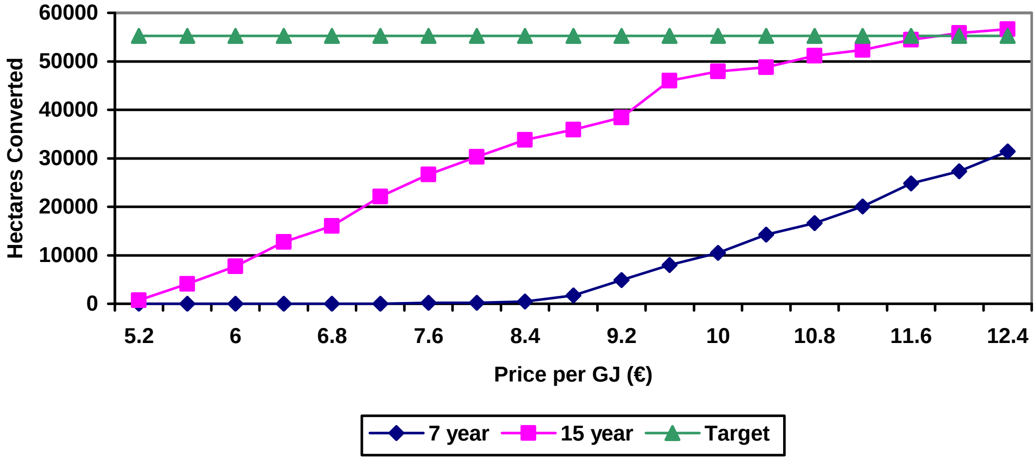
As part of the survey farmers were asked if they had a child who had received formal agricultural education and this variable was used as a proxy for farm succession. Although this explanatory variable is not statistically significant, the large marginal effect of 12% seems to support the hypothesis that having an identified farm successor with agricultural training increases the likelihood that a farmer would be willing to adopt energy crop production. Energy crop production is a long term commitment and it is likely that the operator takes the successor of the farm in to consideration when making a decision on whether to adopt. These three variables; cereals, agricultural education and successor, explain the majority of the variability behind the decision to switch to energy crop production.

The rest of the variables are either statistically insignificant or else have a low marginal effect on the decision variable. Surprisingly, the market gross margin per hectare variable is included among the insignificant variables. This suggests that the returns being made from the existing enterprises are not a significant factor when making an adoption decision. However, the reluctance of Irish farmers in the past to switch to an enterprise with a higher return suggests that there is more to the decision to adopt than the financial considerations. This suggestion is in accordance with Wiemers and Behan (2004) who found an unwillingness to switch enterprises for higher returns when examining the reasons behind the poor uptake of forestry grants.

4.2 LP Results

A LP model was developed to analyze the influence of energy price (per GJ) on the decision of farmers to adopt willow or miscanthus production. The model examines two different scenarios. The first scenario looks at the price per GJ required to achieve the national co-firing target from Willow. The second scenario examines the price per GJ required to achieve the national co-firing target from Miscanthus only.

Figure 1: Effect of price change per GJ on farmer’s decision to adopt willow

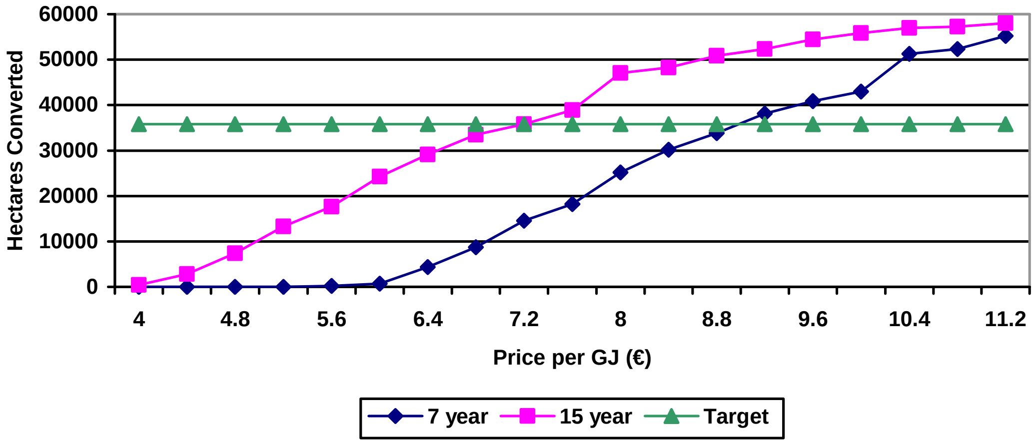


Source: Authors own calculations

It currently costs €3.70 per GJ to produce electricity from burning Peat; at this price no farmers would be willing to begin producing willow, regardless of the project lifespan. Therefore the current price per

GJ is too low to attract a sufficient number of farmers to grow willow and must be increased. It is not until a price of €4.80 per GJ is offered that the first farmers are financially better off to switch from their best conventional agricultural enterprise to the production of willow. This however is dependent on the farmer continuing the enterprise for 15 years and the number adopting is substantially lower than that required to meet the national co-firing targets. If a 7 year timeframe is considered farmers first begin switching to willow production at a price of €7.60. The targets set under the REFIT scheme were reached at a price of €11.90 assuming a 15 year project length. In order to achieve the targets within the 2015 timeframe set out by the scheme, a price of €16.70 would be required.

Figure 2: Effect of price change per GJ on farmer's decision to adopt miscanthus



Source: Authors own calculations

Although there are some farmers better of moving from their conventional agricultural enterprise to the production of miscanthus over a 15 year period at the current price of €3.70 per GJ, there are an insufficient number of farmers to achieve the targets of the REFIT scheme. No farmer would be better off switching from a conventional agricultural enterprise to miscanthus at the price of €3.70 per GJ if a 7 year project lifespan was considered. The target area of 36,000 hectares is first achieved by offering a price of €7.20 per GJ for a 15 year miscanthus project. The target area was only reached at €8.90 per GJ for a 7 year project. This supports the hypothesis that longer term investments in energy crop production generate greater returns due to the substantial set up costs involved in the enterprise.

The influence that an establishment grant has on the price per GJ required to meet the national co-firing targets was also analyzed. Two further scenarios assuming differing grant levels were examined in comparison to the assumed grant which was to be divided equally among all participants in the scheme. The first scenario was based on the assumption that no establishment grant was offered. The second scenario assumed a grant of €1450 per hectare planted was offered to every farmer participating in the scheme. These scenarios were examined at both 7 year and 15 year project lengths. The results are presented in Tables 2 and 3.

Table 2: Influence of Est. Grant for willow on the price per GJ required to achieve national co-firing targets

	7 years	15 years
No Grant	€17.30	€12.00
Full Grant	€14.45	€11.00
Assumed Grant	€16.70	€11.90

The inclusion of an establishment grant has a significant effect on the price per GJ required to entice a sufficient number of farmers to adopt willow production. This is due to the large up-front costs which must be paid by the farmer to establish the crop. An establishment grant helps to offset these costs and so reduces the length of the payback period, making the investment relatively more attractive as the risk is reduced. The effect is not as large over a 15 year timeframe as the establishment costs begin to be offset by the returns generated by the crop.

Table 3: Influence of an Est. Grant for miscanthus on the price per GJ required to achieve national co-firing targets

	7 years	15 years
No Grant	€9.30	€7.30
Full Grant	€7.50	€6.50
Assumed Grant	€8.90	€7.20

The effect of an establishment grant on the price per GJ necessary to achieve the REFIT targets using miscanthus is similar to that of willow. Again the influence of the establishment grant on the price per GJ declines as the project lifespan increases.

5. Conclusions

The results of the probit model suggest that a farmer’s adoption decision depends not only on the financial rewards from growing energy crops but also on a number of personal or farm specific factors. The current system of farming, the agricultural education of the farmer and the existence of a successor are all likely to weigh heavily on any decision to switch to energy crop production.

The LP model takes account of the results of the probit model when identifying constraints to converting to energy crops. This helps identify the most likely farmers to adopt rather than those who would gain the most financially. This type of enterprise is perceived to be risky, and justifiably so considering the relative lack of experience in Ireland of producing energy crops. This will reduce the number of farmer’s willing to adopt.

The price per GJ estimated to be necessary to achieve the national co-firing targets within the designated timeframe of 2015 are €16.70 for willow and €8.90 for miscanthus. If a 15 year project length is considered, the price per GJ required to achieve the targets is lower, €11.90 for willow and €7.20 for miscanthus. As stated earlier the growing of willow and miscanthus in Ireland for the generation of heat and electricity is still a relatively new development and some uncertainty regarding plant performance and yield still exists. Therefore rather than attempting to achieve the co-firing target exclusively from one crop, it may be desirable to rely on a blend of crops. In this case the price per GJ required to reach the government target would need to be somewhere between the willow and miscanthus prices presented above.

There are a number of limitations to the LP approach used that should be taken into account when deciding upon a suitable price per GJ. Firstly, this approach does not capture the risk associated with growing a relatively new crop such as miscanthus or willow relative to long established enterprises such as beef, sheep or cereals production. Rather the model assumes perfect foresight regarding future yields, costs and prices, in the absence of perfect foresight it is likely that the price per GJ paid would need to be higher than that stated in the previous paragraph. Secondly, it does not capture the price effect associated with taking land out of the production of conventional agricultural production. An increase in the production of biomass crops will lead to land being taken out of the production of conventional agricultural commodities; this in turn will lead to a reduction in the supply of these commodities and a resulting increase in their price. This resulting increase in the price for agricultural commodities such as beef or sheep will make them more competitive relative to biomass crops, thus increasing the price per GJ required to achieve government co-firing targets. As a result of these two factors the price per GJ required to achieve the government target is likely to be greater than that estimated.

Aside from the financial aspect already examined, the logistics of transporting willow and miscanthus to the midland power stations is the greatest barrier to the achievement of the national co-firing targets. Biomass energy is bulky and so involves a high transport cost. This reduces the size of the area in which the production of willow and miscanthus can be economically viable and has a limiting effect on amount of farmers whose optimal enterprise is to grow these crops. The cost of transporting biomass crops needs to be calculated in order to generate a viable zone within which it is optimal to produce willow and miscanthus.

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