Examining the socio-economic factors affecting willingness to adopt bioenergy crops

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Numerous studies exist reporting estimates of the theoretical potential for growing bioenergy crops in Ireland; however a knowledge gap exists on the extent to which Irish farmers would actually choose to grow these crops. We investigated the influence of selected individual and farm characteristics on willingness to consider growing bioenergy crops among farm operators in Ireland. A probit model was used to determine the extent to which these selected characteristics influence the willingness of farmers to consider alternative cropping systems. The results showed that willingness to adopt bioenergy crops in Ireland was significantly influenced by the agricultural educational level of farmers, farm size, and farm system. In the final model specification, farm profit, land tenancy, general education level of the farm operator, contact with extension agents and age of the operator were not significant variables affecting willingness to adopt. The policy implications of the research findings are discussed.

Keywords: Farm level decision making, Bioenergy crops, Adoption, Innovation, Probit

1. Introduction

The debate regarding the future role of bioenergy crop production in Ireland has heightened in direct response to a number of issues. Firstly, in response to the reform of the EU Common Agricultural Policy (CAP), Ireland replaced production-indexed farm subsidies with production 'decoupled' single farm payments (SFP) in 2005, based on land area farmed during 2000-2002. The introduction of decoupling is expected to lead to a reduction in Irish livestock numbers (Binfield et al., 2003). The land areas dedicated to both cereal production and sugar-beet in Ireland are also forecasted to decline due to this reform (Thorne, 2004; Thorne, 2006). Secondly, dramatic increases in oil, gas and coal prices have recently made fossil-based electricity and heat production substantially more expensive. These high prices may reflect a new era of higher energy costs perpetuated by limitations in the rate of oil supply and rapidly increasing demand from the growing economies of China and India. Thirdly, the introduction of the EU Emission Trading Scheme (ETS) in 2005 provides financial incentives for carbon-neutral fuels, including bioenergy, under the EU ETS legislation (2003/87/EC; 2004/101/EC).

Ensuing from the aforementioned factors there have been numerous studies estimating the theoretical potential for growing bioenergy crops in Ireland (Rice, 2007), however a knowledge gap exists on the extent to which Irish farmers would actually choose to grow these crops. Hence, this piece of research is focused on modelling the factors influencing the adoption decision at farm level. The hypothesis that there are explanatory variables that could explain the reason why some individual farmers are reluctant to consider alterations to their farm profile is examined. It is hypothesised here that farmers' reluctance to change may be a result of individual and farm circumstances. An understanding of the factors that influence the structural change process is important as it provides information for the policy making process, so that desired structural change can be achieved, based on prevailing social, political and economic goals (Austin et al., 1998). Furthermore, innovative behaviour is a topic of practical as well as academic interest because the willingness of farmers to adopt new techniques is an important determinant of the success of policy initiatives (Willock et al., 1999). In addition to influencing the agricultural policy debate, the understanding of farmer response to policy adjustments has important implications for other sectors in addition to agriculture, as the vibrancy of rural areas can also be affected.

The following section outlines the background to the research question with reference to insights from the literature on the adoption process. This section assists in the identification of explanatory variables that influence the decision making process in the context of bioenergy crop adoption. The next section outlines the econometric model (probit model) that was developed to answer the identified research question. Following this, the data used in the analysis is described and the empirical results of the model are outlined. Conclusions and discussion of the results are then identified, followed by possible areas of future work.

2. Background

As the debate regarding the future role of bioenergy crop production has heightened, so too has the debate regarding the potential uptake or supply of bioenergy crops at farm level in Ireland. Due to the fact that these crops are relatively new to Irish agriculture, limited knowledge from past experiences can be used to assist in the identification of the determinants which will influence the farmer adoption process. There is however a considerable body of literature documenting research on the adoption and diffusion of innovativeness theory (Rogers, 1995). This literature has been widely used to identify factors that influence an individual's decision to adopt or reject an innovation (Boz and Akbay, 2005). While such models do not explicitly model the willingness of farmers to consider or investigate the conversion of land to bioenergy crop production, they do assist in the identification of variables which could characterise 'early adopters'. Boz and Akbay (2005) identified various models in which credence is assigned to individual characteristics and farm level variables in the determination of farm level decision making.

In the context of identifying individual farm characteristics that could influence the farmer adoption process, a number of useful literature sources were identified. To begin with, neo-classical economic theory suggests that individuals are profit maximisers. Clancy et al. (2009) stated that widespread adoption of bioenergy crops in Ireland is only likely when the economic merits of these crops have been proven over an extended period. Many studies have applied this premise to the farmer decision making process, with Perloff (1991), Ryan and Gross (1943) and Hennessy (2002) all citing relative profitability as an explanatory variable of the adoption process in the farming sector. The literature indicates that existing farm profit levels have a significant positive influence on the willingness of farmers to adopt new farming practices. Other farm level characteristics identified in the literature as explanatory variables in the adoption process were farm size (Hennessy, 2002; Rogers, 1995, Ryan and Gross, 1943; Rogers and Pitzer, 1960); production system (Austin et al., 1998; Rosenqvist et al., 2000); and contact with extension personnel (Boahene et al., 1999; Rogers and Pitzer, 1960).

Farm size is hypothesised to have a positive influence on the adoption process, as is contact with extension personnel. Austin et al., (1998) and Rosenqvist et al., (2000) both found that existing farmers involved in crop production were more likely to be early adopters of bioenergy crop production, given that they have previous experience of cropping systems. Furthermore, Austin et al., (op. cit) and Rosenqvist et al., (op. cit) also found a negative relationship between bioenergy crop adoption and total forage area of the farm.

Demographic characteristics identified from the literature that were assumed relevant for this research question included age (Tatlidil, 1989; Brander and Kearl, 1964; Rogers, 1995) and educational level (Rogers, 1995; Ryan and Gross, 1943; Rogers and Pitzer, 1960). Consistent with the literature, it is hypothesised that age of the farm operator will have a negative relationship with adoption. Furthermore, many models have found supporting evidence for the hypothesis of a life cycle (Huffman and Lange, 1989), which indicates alternative propensities of work etiquette at different stages during the life cycle of the farmer. In relation to education level, it is hypothesised that farmer operators with higher levels of agricultural education will be more willing to consider or investigate the growing of bioenergy crops.

All of these issues identified from the literature will be examined in the paper. Empirical studies which have tried to capture the influence of socio-economic variables on farmers' adoption decision have predominantly used a probit or logit model (Rahm & Huffman, 1984; Kebede et al., 1990; Rahji,1998; Vanslembrouck et al., 2002; Damisa, 2007), with probit in particular being very common (Rigby et al., 2001). In these models, farmers are assumed to make adoption decisions based upon an objective of utility maximization. The benefits of adopting these technologies as well as the cost of adoption are likely to vary across farmers that are heterogeneous in the availability of human capital and technical skills, and in other socio-economic characteristics (Nkamleu and Adesina 2000). The results of these papers indicate that the socio-economic characteristics of the farmer influenced the decision they made. Therefore, specific information on the influence of socio-economic characteristics of adoption would be helpful in the design and implementation of more effective programs to promote the adoption of agricultural innovations (Nkamleu and Adesina 2000). The methods used to model the explanatory factors of the adoption process at farm levels are outlined in the following section.

3. Methodology

In this study, farm-related and individual determinants for the adoption of bioenergy crop production among Irish farmers are identified and estimated. This research question was tested empirically by the model:

$$P\{y_i = 1|x_i\} = F(x_i, \beta) \qquad (1.1)$$

This binary choice probit model describes the probability that $y_i = 1$, the vector x_i containing individual and farm level characteristics, and where F is a cumulative distribution function which is bound by the [0,1] interval i.e. $0 \leq F(x_i, \beta) \leq 1$. So, the probability that a farmer has considered or investigated converting land to bioenergy producing crops depends on specified characteristics.

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 regression, it was necessary to compute marginal effects and elasticises to interpret the output from this model.

The goodness of fit of this model was examined using the pseudo R^2 value. It is to be expected that the pseudo R^2 would not be very high in this instance, as cross sectional data is used. Likelihood ratio tests were used to determine the appropriateness of restricted versus unrestricted models i.e. whether or not certain variables are necessary in the model.

4. Data

Data from the National Farm Survey (NFS) (Connolly et al. 2007) was used to examine the research question. The primary objective of the NFS is to collect and analyse information relating to farming activities. To achieve its objective a farm accounts book is recorded for each year on a random sample of farms throughout the country. For 2006, 1,177 farms were included in the analysis. In addition to the individual farm accounting, performance and farmer demographic data collected from the NFS on an annual basis, special studies on individual topics are also conducted. The ‘special study’ survey conducted in 2006 was concerned with, among other issues, farmers’ intentions/considerations regarding converting land to producing bioenergy crops. While this survey was conducted by the NFS not all respondents from the main survey were participants in the special study. As a result, to link data from the main survey with the special study it was necessary to construct a matched balanced dataset. Consequently, the sample size of the final dataset used in the analysis was slightly less than in the original survey, with 998 individual farms included.

In contrast to other empirical studies which have analyzed the determinants of farm structural change, either on the basis of accounting data and census data (such as Kimhi, 1994; Stiglbauer and Weiss, 2000) or survey data (such as Glauben et al. 2004), this approach to examining structural change has an advantage in that the survey data is actually linked to the individual accountancy and demographic data. Thus, the 2006 farm survey database provides data on individual characteristics which will be used as explanatory variables in the probit model. The special survey database provides data on farmers’ considerations regarding planting intentions of bioenergy producing crops, which will provide the data for the dependent variable in the model specified.

The explanatory variables selected which were hypothesised to affect WILLINGNESS were: farm size (SIZE), farm size squared (SIZE2), amount of land owned, expressed as a percentage of total area farmed (LANDOW), amount of land rented out expressed in hectares (RENTOUT), farming system was captured as a dummy variable with 1 representing specialist tillage farms and zero for all other farms (SPECCROPS), total forage area in hectares (FORAGE), farm profit in thousands of euro per farm (PROFIT), education level of the farm operator (EDUC) represented by a scale, agricultural education of the farm operator (AGEDUC) captured as a dummy variable, contact with extension agents (EXTEN) captured as a dummy variable, age of the operator (AGE), and age of the operator squared (AGE2). All of the variables used in the probit model are outlined in Table 1, with variable definitions and the mean values for the sample of farms.

Table 1: Variable Definitions and Descriptive Statistics

Variable	*Variable Definition*	*N*	*Sample Mean*	*Standard Deviation*	*Minimum*	*Maximum*
WILLINGNESS	Willing to produce bioenergy crops (0=No/1=Yes)	998	0.07	0.26	0.00	1.00
SIZE	Farm size in hectares	998	52.42	39.52	5.86	377.20
SIZE2	Farm size squared	958	4308.94	10166.53	34.34	142279.80
LANDOW	Amount of land owned (proportion of Utilisable Agricultural Area)	998	0.93	0.29	0.00	3.85
RENTOUT	Hectares of land rented out	998	0.93	4.77	0.00	52.65
SPECROPS	Specialist crop farm (0 = Not spec; 1 = spec. crop farm)	998	0.07	0.26	0.00	1.00
FORAGE	Total forage area (hectares)	998	43.44	31.35	0.00	346.30
PROFIT	Family Farm Income in 2005 (€'000)	998	27.05	27.97	-32.01	235882.30
EDUC	Education level of the farmer (Scale 1-6)	998	2.13	0.98	1.00	6.00
AGEDUC	Formal agricultural education (scale 0-1, 0=No/1=Yes)	998	0.57	0.50	0.00	1.00
EXTEN	Contact with extension agent (0=No/1=Yes)	998	0.60	0.49	0.00	1.00
AGE	Age of operator (years)	998	53.14	11.96	20.00	83.00
AGE2	Age of operator squared	998	2966.46	1299.89	400.00	6889.00

5. Results

As mentioned above, a standard probit analysis on the likelihood of the farmer considering or investigating the decision to grow bioenergy crops was applied. The estimation results of the specified probit model are presented in Table 2. The model is statistically significant at the 1 percent level or better, as measured by the likelihood ratio test. Overall, the results in Table 2 suggest that the probability of innovation at farm level is significantly influenced by a number of personal and farm characteristics. The marginal effect of each variable on the probability of the adoption decision is presented in Table 3. 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.

The size of the farm is shown to have a significant positive impact on potential adoption behaviour of farmers. The marginal effects in Table 3 show that for a one unit change in farm size, the willingness to grow bioenergy crops increase by .002. It is interesting to note that farm profit is not a significant variable in the adoption decision making process. In a stepwise regression process, farm profit on its own was significant; however when farm size is controlled for and included as an explanatory variable the profit variable no longer remains significant. Since farm profit is positively correlated with farm size (as seen in Appendix 1 in the correlation matrix), one might conclude that existing farm profit is not an important explanatory factor in the adoption decision making process when farm size is accounted for. Hence, the analysis supports the hypothesis that the size of the farm, in terms of land area farmed, is a more reliable estimator of the expected future earnings from bioenergy crop production than the current level of farm income.

Table 2: Results of the probit model on the probability of bioenergy crop adoption

Variable	*Symbol*	*Co-efficient*	*Standard Error*	*Z statistic*	*Prob > |z|*
SIZE	Farm size in hectares	0.02	0.01	3.05	0.00
SIZE2	Farm size squared	-0.00	0.00	-1.62	0.11
LANDOW	Amount of land owned (percent of UAA)	0.08	0.29	0.27	0.78
RENTOUT	Hectares of land rented out	0.01	0.01	0.50	0.62
SPECROPS	Specialist crop farm (0 = Not spec; 1 = spec. crop farm)	0.87	0.23	3.74	0.00
FORAGE	Total forage area (hectares)	-0.01	0.01	-2.53	0.01
PROFIT	Family Farm Income in 2005 (€'000)	0.00	0.01	0.54	0.59
EDUC	Education level of the farmer (Scale 1-6)	0.06	0.08	0.82	0.41
AGEDUC	Formal agricultural education (scale 1-2, 1=No/2=Yes)	0.76	0.20	3.71	0.00
EXTEN	Contact with extension agent (1=No/2=Yes)	-0.07	0.16	-0.45	0.65
AGE	Age of operator (years)	-0.04	0.04	-0.92	0.36
AGE2	Age of operator squared	0.00	0.01	0.84	0.40
_cons		-1.82	1.09	-1.66	0.10
Number of observations	998				
LR chi2	129.93				
Prob>chi2	0.000				
Log Likelihood	-187.99				
Pseudo R2	0.2488				

Table 3: Marginal effects from probit model

SYMBOL	*Marginal Effect*	*Standard Error*	*Z statistic*	*Prob > |z|*
SIZE	.002	.00053	2.93	0.003
SIZE2	-.000	.00000	-1.61	0.107
LANDOW	.007	.02402	0.27	0.784
RENTOUT	.000	.00113	0.50	0.620
SPECROPS	.134	.05545	2.42	0.016
FORAGE	-.000	.00039	-2.41	0.016
PROFIT	.000	.00000	0.54	0.593
EDUC	.005	.00643	0.82	0.415
AGEDUC	.060	.01479	4.11	0.000
EXTEN	-.006	.01370	-0.45	0.655
AGE	-.003	.00343	-0.92	0.359
AGE2	.000	.00003	0.84	0.399

In accordance with similar research conducted on the adoption decision making process, an additional two land area variables, namely total land owned as a percentage of Utilisable Agricultural Area (UAA) and total land area (hectares) rented out, were included as explanatory variables in the model. Neither of these two variables were significant, indicating that size of the farm is the only important variable in the adoption decision making process and land tenure systems are not important explanatory variables, as was seen in other studies such as Rosenqvist et al., (2000).

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 bioenergy crops, which one could consider as a proxy for tradition or experience contributing a significant role to the adoption decision. The marginal effects in Table III show that being a specialist tillage farmer increases the probability of considering adoption of bioenergy crop production by 10 percent. Further evidence of the role of traditional farming practices influencing the adoption decision is shown by the variable total forage area, which shows forage area has a significant negative effect on the willingness of farm operators to investigate or consider the growing of bioenergy crops.

The influence of and inter-relationships between individual farm operator characteristics on the willingness to consider bioenergy crop production is worthy of note. When the age of the operator is controlled for on its own (in a step wise regression) it appears to be negatively correlated with the willingness to adopt new farming practises, whereby younger farmers are more willing to consider bioenergy crop production, and there is no evidence of the existence of a significant lifecycle influence. However, when the agricultural education level of the farm operator is controlled for in the model, agricultural education appears as a highly significant variable and age of the operator no longer remains as a significant explanatory variable. Hence, one could consider that age of the operator was not initially explaining a time horizon factor, i.e. younger farm operators were not willing to consider bioenergy crop production because of their reduced discount rate applied to future cash flows, but rather age of the operator was a proxy for education levels of the operator. The inter-relationship between the age and education variables included in the model show that age on its own is not a significant variable in the adoption decision making process of bioenergy crop production but agricultural education of the farm operator is an important factor. Hence, farmer operators with agricultural education may be more open to new ideas and be more willing to investigate alternative farming systems. The marginal effects reported in Table III show that farm operators with formal agricultural education are 6 percent more likely to consider growing bioenergy crops than farm operators with no formal agricultural education.

Contact with extension agents did not appear as a significant variable affecting the adoption decision. While the relationship was positive it was not significant. This is contrary to other findings in the adoption literature where contact with extension agents was a significant factor affecting the adoption decision (Boahene et al., 1999; Rogers and Pitzer, 1960).

6. Conclusions

The purpose of this study was to determine the influence of farm and individual level characteristics on the willingness of farmers to investigate the adoption of bioenergy crops in Ireland. Innovation theory was used as a framework to develop an empirical model. The probit regression procedure was used to determine the extent to which the selected explanatory variables influenced the willingness of the farmer to consider adopting the aforementioned crops. Overall the results confirm that both farm and individual farmer characteristics are important in the adoption process.

The research findings related to the farm characteristics: system of farming and farm size, are consistent with the general literature on the adoption process within agriculture. Consistent with adoption theory (Boz and Akbay, 2005), this research has shown that farm size is a positive socioeconomic characteristic, whereby farm size has a positive impact on the willingness of farmers to consider or investigate the growing of bioenergy crops. Given that existing farm profit level was not a significant explanatory factor in the adoption process when farm size was accounted for, it could be concluded that size of the farm is a more reliable estimator of the expected future earnings from bioenergy crop production than the current level of farm income. This finding 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.

Unlike other empirical research which has applied innovation theory to examine the adoption process in agriculture, the importance of extension contact in promoting bioenergy crop adoption in Ireland did not appear as a significant variable in this research. Given that a number of the bioenergy crops being highlighted as suitable for Irish growing conditions (such as willow and miscanthus) incur substantial establishment costs and at the time the survey was conducted no establishment grant aid was available from the government, it is possible that farmers and extension agents were adopting a wait and see approach. Rice (2007) highlighted the need to improve the profitability of growing and processing bioenergy crops if the industry is to develop to a significant scale. Also, development of extension activities must be based on, and take into account, the socioeconomic status of the farmer. As shown in this research a number of variables are highly significant in influencing the adoption process, whereas other farm level and individual specific variables are less significant in the adoption process. Following from recommendations outlined by Boz and Akbay (2005), agricultural extension services must identify and work together with early adopters, or potential early adopters. Once the early adopters of the innovation or cropping system accept the idea they will play an important part in influencing other people in the industry. This can facilitate the work of extension agents in promoting the crops and lowering program delivery costs.

At the policy level, national government must put in place a coherent policy to encourage bioenergy crop production in order for Ireland to meet national targets for bioenergy production set by the European Commission. Mullins (2007) criticised Ireland's 'piecemeal approach to biofuel production' which has hindered the ability of biofuel production companies to operate in the Irish market. The importance of the research findings outlined in this paper is that policy makers will now be assisted in distinguishing between firms regarding their likelihood of bioenergy crop adoption.

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Appendix 1: Correlation Matrix: Coefficients and Significance Levels

	WILLINGNESS	SIZE	SIZE2	LANDOW	RENTOUT	SPECROPS	FORAGE	PROFIT	EDUC	AGEDUC	EXTEN	AGE	AGE2
WILLINGNESS	1.00												
SIZE	0.22	1.00											
	0.00												
SIZE2	0.18	0.88	1.00										
	0.00	0.00											
LANDOW	-0.02	-0.08	0.04	1.00									
	0.53	0.01	0.19										
RENTOUT	0.09	0.16	0.20	0.48	1.00								
	0.01	0.00	0.00	0.00									
SPECROPS	0.35	0.17	0.15	0.06	0.18	1.00							
	0.00	0.00	0.00	0.05	0.00								
FORAGE	0.02	0.81	0.65	-0.06	0.11	-0.14	1.00						
	0.47	0.00	0.00	0.05	0.00	0.00							
PROFIT	0.19	0.62	0.46	-0.04	0.11	0.15	0.57	1.00					
	0.00	0.00	0.00	0.26	0.00	0.01	0.00						
EDUC	0.13	0.17	0.12	-0.03	0.12	0.12	0.14	0.21	1.00				
	0.00	0.00	0.00	0.34	0.00	0.00	0.00	0.00					
AGEDUC	0.19	0.23	0.10	-0.09	0.01	0.12	0.23	0.32	0.28	1.00			
	0.00	0.00	0.00	0.01	0.65	0.00	0.00	0.00	0.00				
EXTEN	0.09	0.22	0.11	-0.08	0.00	0.08	0.18	0.28	0.09	0.29	1.00		
	0.01	0.00	0.00	0.02	0.85	0.02	0.00	0.00	0.00	0.00			
AGE	-0.09	-0.07	-0.01	0.20	0.07	-0.00	-0.08	-0.14	-0.40	-0.40	-0.16	1.00	
	0.00	0.02	0.64	0.00	0.03	0.98	0.01	0.00	0.00	0.00	0.00		
AGE2	-0.09	-0.07	0.25	0.21	0.08	0.00	-0.08	-0.15	-0.40	-0.40	-0.16	0.99	1.00
	0.01	0.02	0.43	0.00	0.02	0.99	0.01	0.00	0.00	0.00	0.00	0.00	