Energy Policy 36 (2008) 3062–3068

Contents lists available at ScienceDirect

Energy Policy

journal homepage: www.elsevier.com/locate/enpol

The effects of policy incentives in the adoption of willow short rotation coppice for bioenergy in Sweden

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ARTICLE INFO

Article history:
Received 14 February 2008
Accepted 26 March 2008
Available online 4 June 2008

Keywords:
Bioenergy policy
Adoption models
Energy plantations

ABSTRACT

The effect of policy incentives in the development of short rotation willow plantations for bioenergy is studied by using an aggregate adoption model based on sigmoidal curves for the Swedish municipalities. A total of 56 municipalities were studied, with 891 farmers that planted willow during the period 1986–1996. The model included variables related to the subsidies applied, the taxation on fossil fuels, the development of the wood-fuel consumption by the district heating systems, and the geographical and socio-economic characteristics of the municipality. Results of the simulations using the model show an increment of almost 70% of farmers planting willow during the period studied when the subsidy and tax incentives and the increments of the wood-fuel capacity by the district heating system took place. This study gives tools for future policy implementations in order to achieve the goals of the energy strategies.

1. Introduction

Bioenergy is an important target for the European Commission's policy plans for energy such as the Biomass Action Plan (CEC, 2005), the Energy Policy for Europe (CEC, 2007) and the objectives of the proposal for a directive on the promotion of the use of energy from renewable sources (CEC, 2008). As wood-fuels are becoming increasingly important, there is a foreseeable scenario of competition between the emerging renewable energy sector and the traditional uses of the forest everywhere in the world. To fill the gap between this new demand of biomass from the forest and the current supply levels, a substantial increase in the area of short rotation plantations in the European Union (EU) will be required. In fact, it is estimated that at least 27 Mtoe (93 TWh) are required from short rotation production systems in order to accomplish the goals of bioenergy production (Kuiper et al., 1998), which means the establishment of approximately 8 M ha of bioenergy plantations on agricultural land (given the current estimated rates of annual biomass production). According to the estimations of the EEA (2006), the EU biomass production potential from agricultural crops without harming the environment is 43–46 Mtoe in 2010, and more than 100 Mtoe in 2030.

Although an enlargement of the areas planted is expected in the next few years (Berndes and Hansson, 2007), currently the biomass consumption from energy crops (including all types, herbaceous and short rotation coppice) on agriculture land is still only 2 Mtoe (CEC, 2005). Among the different crops proposed for energy uses, willow (*Salix*) is one of the few that has been planted commercially to a significant extent in the EU (Ericsson and Nilsson, 2006). During the last two decades, more than 16 000 ha of short rotation willow plantations were established in Sweden, which is about 0.5% of the total arable land in the country (Larsson and Lindegaard, 2003), making Sweden the leader in commercial plantations of short rotation willow in Europe. However, short rotation willow plantations are a new cultivation for farmers when compared with traditional agriculture crops, and different measures were used during the 1990s by the Swedish government, in order to encourage the adoption of willow by the Swedish farmers.

During the period 1991–1996, a generic subsidy of 9000 SEK ha^{-1} (with variation according to the land fertility) was available for farmers who transferred a part of their crop land from cereal production to other activities and, additionally, a specific subsidy of 10 000 SEK ha^{-1} was available for willow plantations, plus in some cases 4000 SEK for fencing (Rosenqvist et al., 2000; Johansson et al., 2002). These subsidies almost covered the starting costs of the new plantations (Rosenqvist et al., 2000). At the same time, taxes on sulphur and CO_2 for fossil fuels in heat production were introduced in 1991, and were progressively increased in the following years: 0.25 SEK/kg CO_2 in 1991, 0.32 SEK/kg CO_2 in 1993, and 0.36 SEK/kg CO_2 in 1996 (Johansson et al., 2002; Ericsson et al., 2004), which made biofuels more competitive, since they were exempt from these taxes. In addition, the use of biofuel by the district heating sector was already well

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doi:10.1016/j.enpol.2008.03.036

established before 1990, and grew during the following decade, providing a market and infrastructure for the harvested willow chips. These measures were considered the main driving force in the adoption of short rotation willow coppice by Swedish farmers (Rosenqvist et al., 2000; Johansson et al., 2002). Their total effect in the country was evident; since 1997 when the planting subsidy was reduced to less than a third, the number of new plantations dramatically decreased.

The adoption of short rotation willow coppice by Swedish farmers was studied in Sweden (Roos et al., 2000) observing a large set of farm-related factors influencing adoption, including characteristics of the farmer (age, tenancy, level of mechanisation of the farm,…), uses of the farm's land and geographical location factors. The results proved that the adoption of energy crops could be predicted, and gave fundamental clues about the variables that could affect that decision. However, there is limited knowledge about the effects that the implementation of the policy measures had on the pattern of the farmer's adoption of short rotation plantations over time based on extensive empirical data.

In general, the studies on the adoption pattern of new cultivations are based on the initial works of Griliches (1957) studying the cultivation of hybrid corn varieties in the US by using sigmoidal curves to define the aggregate number of adopters and their evolution in time. The use of sigmoidal shapes to explain the aggregated adoption on a specific location has been supported by later theoretical studies and empirical evidence (a review of works using this approach can be found in Rubas, 2004). As any other innovation, at the beginning only few farmers are willing to invest in what is perceived as a high risk enterprise. As time passes, more farmers are convinced and adopt the innovation, until the least risk-takers finally join and a maximum number is reached. For each spatial unit of aggregation an adoption ceiling is defined, which is assumed to be a function of the social and economic variables of the area (including factors such the existence of a market for willow, the compatibility of willow cultivation with the current land uses, the risk-aversion of the local farmers, the opportunity costs,…). This ceiling can be modified by policy and institutional measures introduced to encourage the adoption, which are considered as exogenous variables.

This study focuses on the temporal and geographical variation of the adoption of short rotation willow coppice by the Swedish farmers. The focus is on the aggregated number of willow growers in Sweden, and its variation over time. The aim is to identify the effects that the different incentives for willow cultivation meant to the adoption and expansion of commercial plantations since the first ones in 1986, till the reduction of the planting subsidies in 1997. This is assessed by an aggregate adoption model to explain the pattern of the number of farmers that have started cultivations of willow short rotation forestry for biomass, based on sigmoidal curves with variable maximum ceilings. Using this concept, our assumption is that the maximum number of adopters in a specific municipality is defined by its socio-economic characteristics as well as by a variable economic context subject to policy incentives. A more detailed understanding of the effects of the policy incentives as well as the geographical distribution of the farmers growing willow would help policy makers in countries expanding their area of short rotation forestry.

2. Methodology: modelling adoption in 1986–1996

2.1. Data from willow growers in Sweden

The data from willow plantations established on private farms in Southern and Central Sweden were provided by Lantmännen Agroenergi AB (formerly known as Agrobränsle AB), which manages planting and administrates the harvesting of willow plantations. The dataset included the location of the plantations, the owner and the year of establishment. Data with inconsistent records or lacking information regarding the ownership of the plantations or the location were excluded from the calculations. In addition, municipalities with a negligible number of willow growers were not included in the dataset of the study, defining the limit as more than 5 growers in 1996. All plots were geo-referenced to a 1 km precision. They covered the area from 55°20′N to 61°29′N and from 11°33′E to 18°56′E (Fig. 1). The models were based on a total of 891 growers from 56 municipalities, during the period 1986–1996. The data regarding the wood-fuel consumption by the district heating systems were provided by Svensk Fjärrvärme AB (Table 1).

2.2. Statistical methods

The predicted variable of the model was the accumulated number of growers that planted willow for bioenergy for the first time (adopters) in a municipality. The adoption was modeled using sigmoidal curves, and the predictors were chosen so as to show the factors that can affect adoption by farmers. All predictors had to be significant at the 0.05 level, and the residuals had to indicate a nonbiased model.

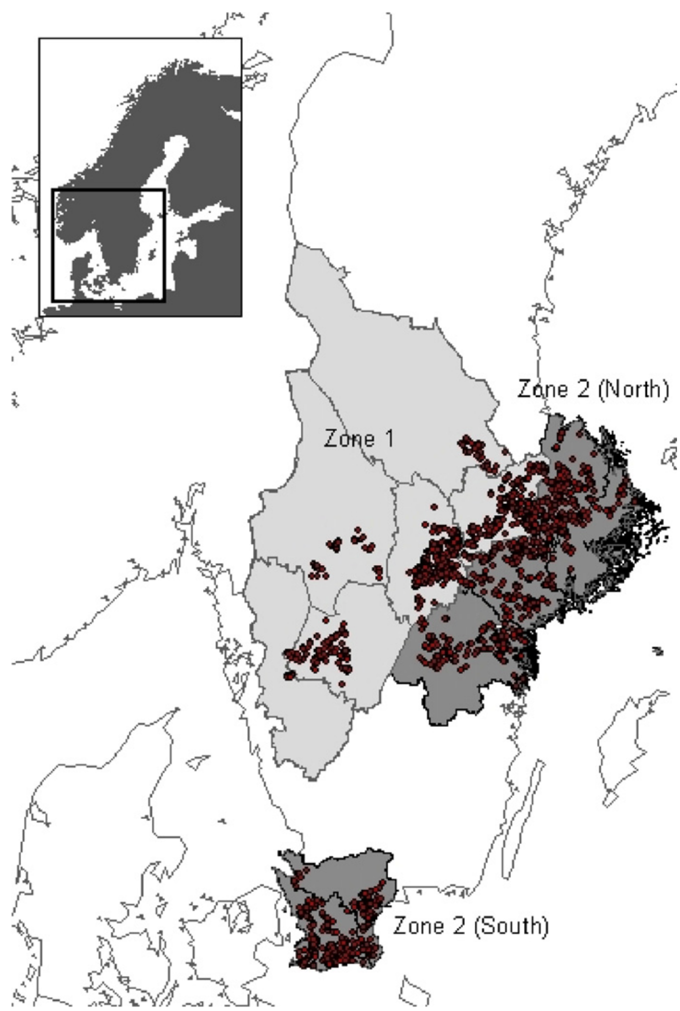

Fig. 1. Commercial willow growers in Central and Southern Sweden included in the models. The model includes dummy variables for three zones: *zone* 1, *zone* 2 (*North*) and *zone* 2 (*South*). *South* is specifically referred to the regions of Kristianstad and Malmöhus.

Table 1
Mean, standard deviation (S.D.) and range of the data obtained and the variables used in modelling

Variable	Mean	N	S.D.	Maximum	Minimum
N	5.89	682	9.196	65	6
agr (1000 ha)	20.30	682	12.206	57.89	1.38
BAR_{sd} (t ha^{-1} yr^{-1})	4.55	682	0.806	6.52	3.35
Grass (1000 ha)	2.33	682	2.302	10.64	0.12
iwf (GWh)	66	682	156	885	−21
Tax (10 000 SEK)	2.13	682	1.01	4.56	1.51

N: aggregated number of willow growers of the municipality.
agr: agricultural land of the municipality as estimated in 1995 Statistics Sweden (1995).
BAR_{sd} average for 2003–2005 of standard yields of oats in agronomical districts as calculated by the Swedish Board of Agriculture (2005).
Grass: area of grasslands land of the municipality as estimated in 1995 Statistics Sweden (1995).
iwf: increment in the use of wood fuel by the district heating plants respect 1991. Data provided by the Swedish District Heating Association.
Tax: amount of revenues from energy taxes in SEK for the period 1990–1996 as estimated by Johansson et al. (2002).

The number of adopters was grouped by municipalities and regions. Therefore, due to the hierarchical structure of the data, a mixed model including fixed and random factors was used (Pinheiro et al., 1994). The residual variation was divided into between-municipalities and between-regions components. The nonlinear models were estimated using the maximum likelihood procedure of the nonlinear mixed model statistical package of R software (Pinheiro et al., 2007).

A large set of alternative variables and their combinations were tested before the final version of the model was chosen. The tested variables included: total number of holders, average age of the farmers, forest area, number of horses, number of cows, average soil textures, proportion of large lands by farmer ($>$50 ha),…, all of them at a municipality level. Many of them were correlated or were not significant. The final version was selected as to have a good fit with the minimum number possible of variables, to represent the evolution of the adoption pattern and to have a low bias.

The adoption model of commercial Swedish willow plantations during 1986–1996 was modeled according to

$$N_{lkt} = \frac{a + \mu_l + \mu_k}{1 + e^{b(t-c)}} + \varepsilon_{lkt} \quad (1)$$

where the parameter a is the maximum adoption ceiling, defined as

$$a = \beta_1 \frac{agr_l^2}{1000} + \beta_2\, ORE\, agr_l + \beta_3\, SUB\, agr_l + \beta_4\, iwf_k\, agr_l + \beta_5 \frac{tax\, agr_l}{10\,000} + NOR \times (\beta_6\, grass_l + \beta_7\, bar_l + \beta_8\, bar_l^2) \quad (2)$$

and parameters b and c are defined as

$$b = \beta_9 + \beta_{10}\, Z2 \quad (3)$$

$$c = \beta_{11} + \beta_{12}\, Z2 + \beta_{13}\, SOU \quad (4)$$

where N_{lkt} is the accumulated number of growers planting willow for the first time until year t, in municipality l in region k, *agr* is the agricultural land of municipality l in 1000 ha as estimated in 1995 (Statistics Sweden, 1995), *ORE* is a dummy variable for the region of Örebro, *SUB* is a dummy variable for the period of subsidies for willow plantations of 10 000 SEK ha^{-1} (1991–1996), *iwf* is the increment in the use of wood-fuel by the district heating plants compared with 1991 in region k and year t (TWh), *tax* is the amount of revenues from energy taxes in SEK for the period 1990–1996, based on Johansson et al. (2002), *NOR* and *SOU* are dummy variables that refer to the municipalities of the Central–North and South part (Kristianstad and Malmöhus regions) of the country, respectively, *grass* is the grassland area in hectare of municipality l as estimated in 1995 (Statistics Sweden, 1995), *bar* is the average yield of barley for the period 2003–2005 by municipality as extracted from the agricultural districts (Swedish National Board of Agriculture, 2005), in t ha^{-1} yr^{-1}, *Z2* is a dummy variable that refers to the regions with total increments of biofuel consumption by the district heating systems above 100 GWh during the period 1994–1996 (see Fig. 1, zone 2). Subscripts l, k, and t refer to municipality, region and time, respectively. μ_l, is the between-municipality random factor, independent and identically distributed with mean = 0 and constant variance ($\sigma_{mun}{}^2$). Finally, ε_{lkj} is the between-years random factor for year t, municipality l, and region k, with mean equal to 0 and variance equal to $\sigma_t{}^2$. Initially, both random parameters, municipality and region, were included in the model. However, the between-region parameter ($\mu_{k,}$) was not significant and was therefore excluded from the final version of the model.

The barley yields used as a predictor were obtained according to the Swedish agricultural districts (Swedish National Board of Agriculture, 2005), which are defined by areas of similar agricultural productivity, and do not always have common boundaries with the municipalities. Therefore, barley yields were first matched to each plantation using the boundaries of the agricultural district, and then included in the model as a value for each plantation independent of the municipality.

The models were evaluated quantitatively by examining the magnitude and distribution of the residuals for all possible combinations of variables, aiming at detecting obvious dependencies or patterns that indicate systematic discrepancies. In order to determine the accuracy of the predictions, absolute and relative biases and root mean square errors (RMSEs) were also calculated (Vanclay, 1994).

3. Results of the model

The results of the model are presented in Table 2. The coefficient of determination (R^2) of the proposed model was 0.83 for the fixed part of the model, and 0.98 when the between-municipalities random factor was included (Fig. 2).

Table 2
Estimates, standard error (S.E.) and significance level of the parameters and variance components of the willow yield models

Parameter	Estimate	S.E.	*p*-Value
Eq. (1)			
β_1	13.552	1.721	0.000
β_2	0.886	0.143	0.000
β_3	0.029	0.004	0.000
β_4	0.155	0.025	0.000
β_5	0.148	0.031	0.000
β_6	−2.415	0.535	0.000
β_7	7.330	2.202	0.001
β_8	−1.470	0.503	0.004
β_9	0.977	0.045	0.000
β_{10}	−0.156	0.055	0.005
β_{11}	5.064	0.058	0.000
β_{12}	1.638	0.101	0.000
β_{13}	2.854	0.167	0.000

S.E.: standard error of the estimations are given in parenthesis.
p-Value: significance of the estimation of the parameter.

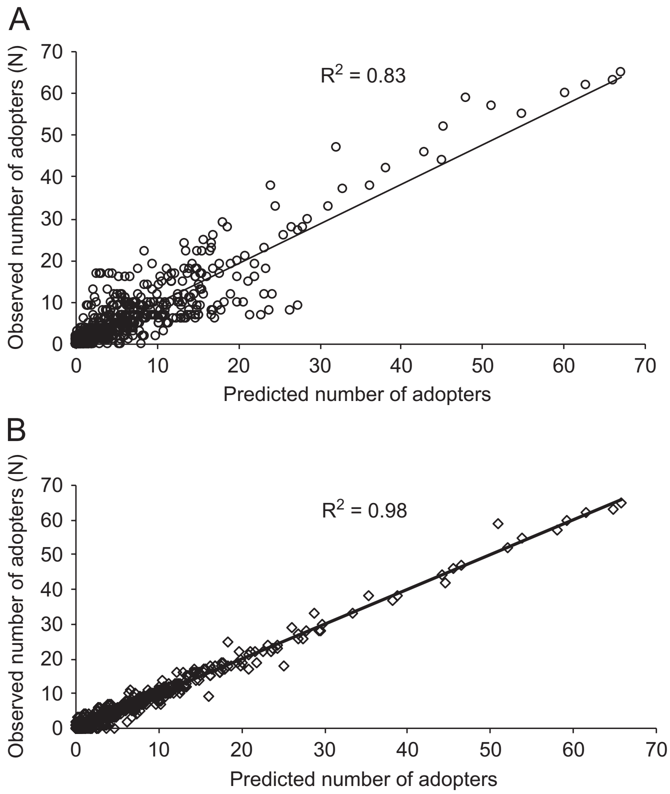

Fig. 2. Measured and predicted number of farmers adopting willow plantations in Sweden, according to the model proposed using the fixed part of the model (A), both fixed and random parameters (B).

The parameter estimates included in the model were significant. As expected, the effect of available agriculture land was positive, as well as the effect of subsidies and consumption of wood-fuel by the district heating systems. Also the cereal productivity measured by the barley yields showed a positive effect, although its marginal influence decreased in the areas of high yields resulting in a negative coefficient of the squared barley yield. The grassland area showed a negative correlation in the areas of the Centre and North of the country. Finally, the region of Örebro showed higher adoption than the rest of the country.

For the fixed part of the model, the absolute and relative bias were 0.032% and 0.55%, respectively; and the absolute and relative RMSE were 3.84% and 65.5%, respectively. In addition, the mean bias of the fixed part of the model was examined by plotting the residuals as a function of the predictors of the model (Fig. 3). A slight trend was observed in the available agriculture land, but no overall obvious dependencies or patterns that indicated systematic trends were observed in the rest of the variables analysed. It should be taken into account that a part of the residual variation of the fixed part is explained by the random factors included in the model.

The predictions of the model reproduced fairly well the variations in the screened number of growers that adopted willow in the whole of Sweden during 1986–1996. The results of the model allow different simulations to perform scenarios without incentives. The version when the incentives are removed show a reduction in the total number of adopters of 70% for the period 1991–1996 (Fig. 4).

In the Southern and Central-Eastern areas of the country, the inclusion of the incentives meant a higher increment, in absolute and relative terms, as compared with the predictions without incentives, whereas the increment was much smaller in the Central and Western areas of the country defined by zone 1 (Fig. 5). The real demand of wood-fuels by the district heating systems increased proportionally in the Southern and Central-Eastern areas compared with the area defined by zone 1 (Fig. 6) during the period studied.

4. Discussion

4.1. A model for adoption of short rotation coppice for energy

This study presents a model to study the aggregate adoption rate of willow plantations for bioenergy amongst Swedish farmers, and to evaluate the impact of policy incentives on it. The database used in the calculations included 1013 farmers growing willow in Sweden for the period 1986–1996. This figure is quite close to the data from the farm register (1995) used in other studies (Roos et al., 2000), although did not include the absolute number of growers, since incomplete records were excluded (some records lacked the geographical location of the farmers, or the specific year of the first plantation). The model used municipalities with more than 5 growers in 1996, since otherwise would not be enough data to define the curves. Therefore, the final number of growers included in the model was reduced from 1013 to 891 farmers.

The unit of aggregation used was the municipality. This level of aggregation makes a great number of variables available from official records. Arguably, farmers from the same municipality interact more among themselves and share more information regarding agricultural practices, including willow cultivation, which makes municipality level a good unit of aggregation from a sociological point of view. Although municipalities with a negligible number of growers were excluded, still a significant number of municipalities had less than 10 growers by 1996, which partially explains the slight underestimation of the predictions. The next level of aggregation included in the models, the region, proved to be not significant and was dismissed. It is quite possible that much of the variability between regions is already explain by the different zones included in the model.

The overall results seem to confirm the sigmoidal curve as a valid tool to describe the diffusion of willow cultivation amongst farmers, as has been supported by other theoretical and empirical studies in agriculture (Rubas, 2004). The approach taken aimed to model the absolute number of adopters for each municipality, rather than a relative measure (such as the percentage of adopters). This implies the use of a variable to balance the different size of the municipalities. Given that willow coppice is cultivated as an agricultural crop, the total area of agricultural land is an easy to measure variable that directly correlates with the maximum possible number of adopters of willow. On one hand, municipalities with large areas of agricultural land have more farmers and thus more potential adopters. On the other hand, the larger the agricultural land available for a fixed number of farmers, the wider the different uses (including willow coppice) can be, which may explain why this correlation seems not to be linear. In addition to the presented model, alternative models were tested including the total number of agricultural holders for each municipality, with similar results. In all cases, the final predictions presented a slight negative bias for large municipalities, possibly due to the effect of municipalities with low levels of adopters.

The model shows better adoption rates in areas with reduced area covered by grasslands and average cereal yields. As found in previous studies (Roos et al., 2000; Rosenqvist et al., 2000), the area for pastures had a negative relationship with the number of adopters in a municipality, and the same effect was found when the model included variables related to animal production

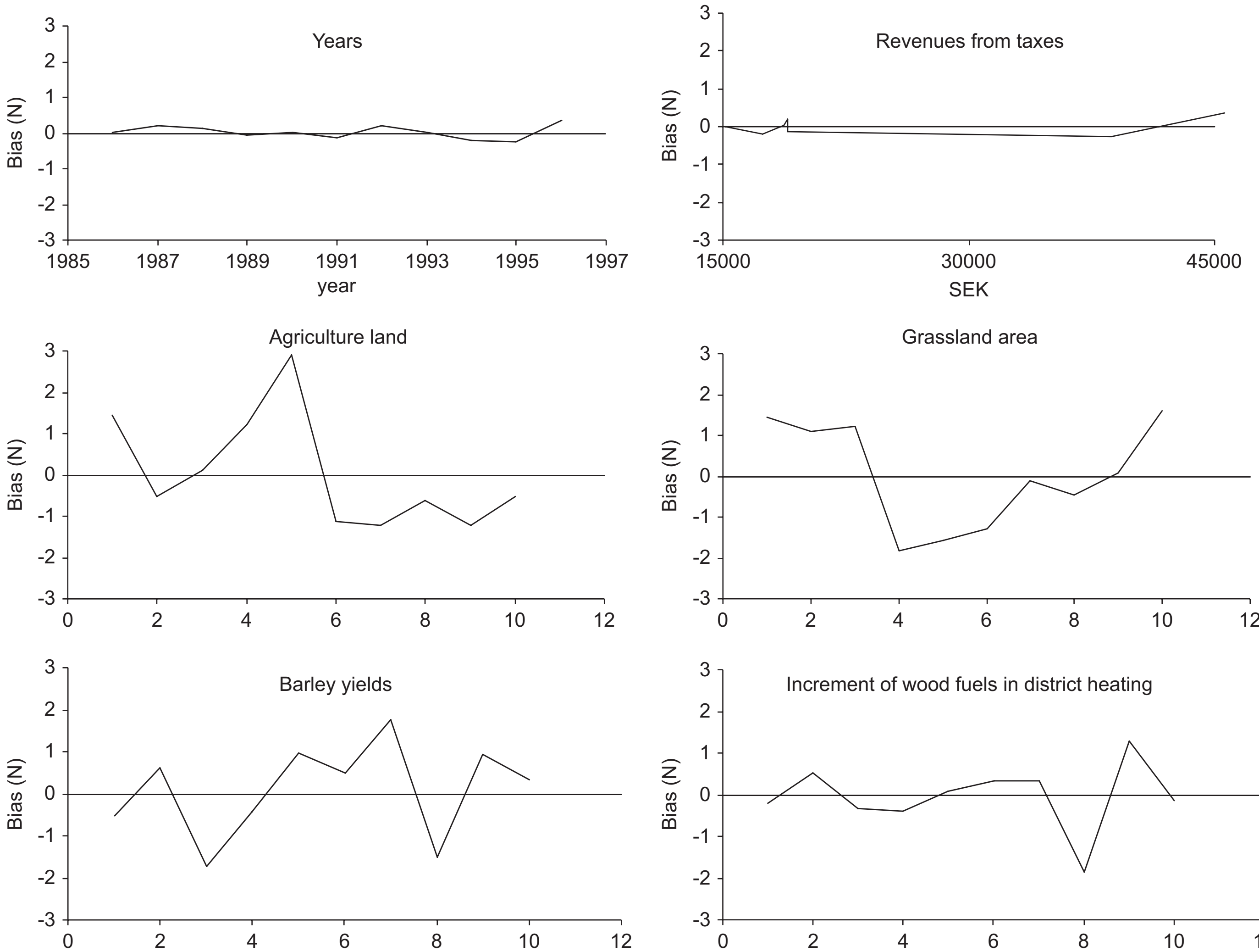

Fig. 3. Mean residuals (bias) of the predictions of the fixed part of the model as a function of the variables used. *N* refers to the aggregated number of adopters. The values of the variables have been divided in 10 groups of equal number, except for the year of adoption (t) and the revenues of oil taxes.

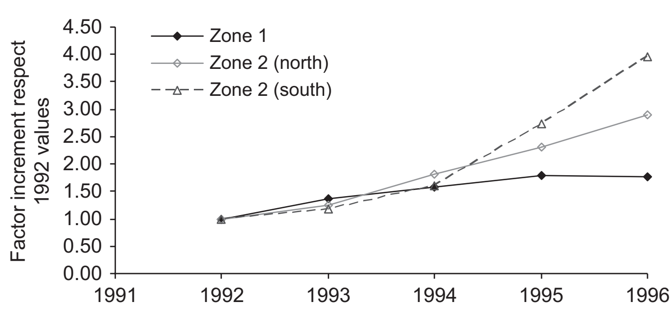

Fig. 4. Changes of the demand of wood-fuels by the district heating systems aggregated according to the studied zones.

(such as number of cows, number of horses, etc.). This can be explained as a conflict in land use between willow coppice and animal husbandry, since farmers with cattle may prefer to keep larger areas set-aside to feed their animals (Roos et al., 2000). About other possible conflicting uses, profitability calculations for plantations showed that willow is less competitive in regions with high yielding cereal or in areas with lower productivity where they can conflict with other uses (like fodder or cattle production), being more appealing in medium productivity areas (Rosenqvist et al., 2000; Larsson and Lindegaard, 2003).

4.2. *The effects of policy incentives on the adoption*

In addition to the characteristics of the municipality, the study of the specific effects on adoption of the policy measures implemented to encourage willow cultivation seems to be more complex. In general, the subsidies for willow have been revealed as a necessary tool to promote the plantations, and after the reduction of the subsidies in 1996, the expansion ceased. Due to the economic characteristics of willow cultivation, subsidies on willow act to neutralise the negative liquidity during the first years leading to higher profitability and reducing the economic risks taken by the farmer, encouraging the diffusion and adoption of willow (Johansson et al., 2002). Planting willow for bioenergy can be considered as a long time investment: it is calculated that the economic lifespan of a willow plantation is about 20–25 years (Ledin and Willebrand, 1996; Nordh, 2005), although the harvests (and therefore the incomes) are made every 3–5 years. The first years mean a significant investment for the farmer, since the establishment costs already amount to about 20% of the total cost of the production (Rosenqvist et al., 2000) and, in general, the first rotation is significantly less productive than the subsequent ones.

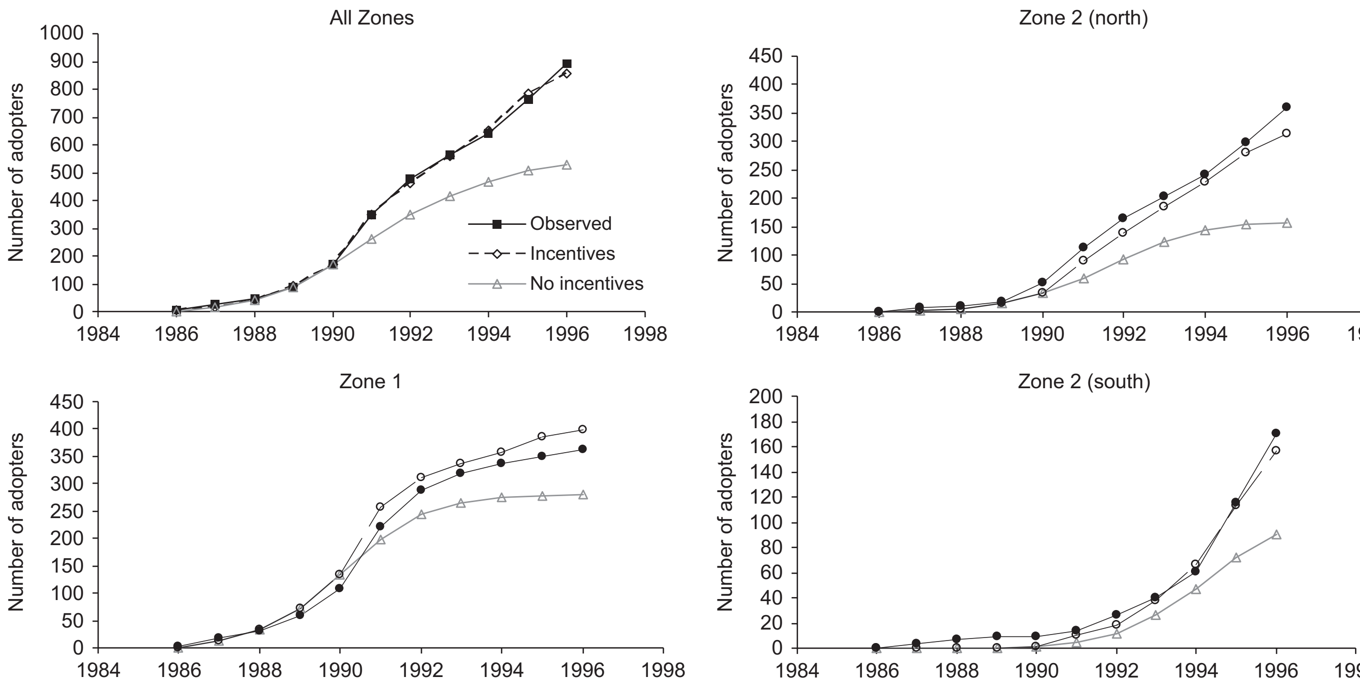

Fig. 5. Results of the observed and predicted values by municipalities, aggregated by zones. For the *no-incentives* predictions, the *tax* parameter is fixed to 1990 levels, no subsidies assumed and no increment of wood-fuel consumption by the central heating systems.

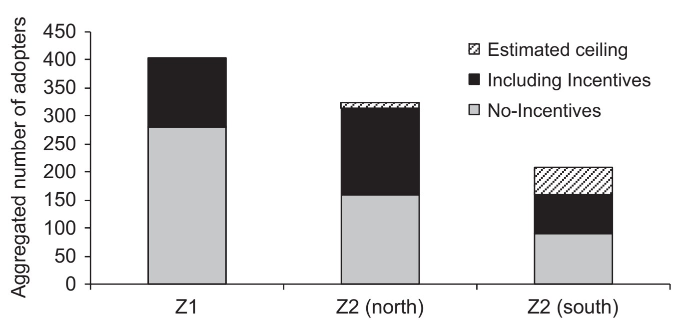

Fig. 6. Predicted aggregated number of adopters per zones in 1996, resulted from the model. For the *no-incentives* predictions, the *tax* parameter is fixed to 1990 levels, no subsidies assumed and no increment of wood-fuel consumption by the central heating systems.

With no subsidies, this situation reduces the adoption of willow in the first steps of its diffusion, and in general, crops with high levels of risk and low anticipated profitability have fewer possibilities to be adopted (Abadi Ghadim and Pannel, 1999; Marra et al., 2003).

The taxation system also explains much of the increase in the utilisation of biomass in Sweden during the 1990s (Johansson et al., 2002). Taxes on sulphur and CO_2 for fossil fuels in heat production increased significantly after 1992, making wood-fuels more competitive (Larsson and Rosenqvist, 1997). This also influenced the demand for wood-fuels by the district heating plants in all Sweden, acting as a pulling effect on farmers, and contributing to the development of the logistics associated with management of the willow chips. As has been observed (Rosenqvist et al., 2000), the existence of a district heating system with an increasing demand for biofuels also increases the confidence of the growers in the development of a market for willow chips and encourages the planting of willow in the area.

The increments in the utilisation of wood-fuel by the district heating plants are a valid indicator of the demand of wood-fuel in the areas nearby, which supposes around 21% of the total biomass use in all Sweden (Johansson et al., 2002). These increments reflect the enlargement of their wood-energy capacities or the replacement of oil boilers by wood-fuel-adapted technologies, which are becoming more competitive with the increasing taxes on fossil fuels. In the model, the energy generated from wood by the heating district plants was only available after 1991, but it can be assumed that the increments prior to this time were comparatively small. This is a reasonable assumption since the utilisation of bioenergy at the national level in both the small scale and district heating was comparatively stable before that time, with only a relatively very small increment from 1986 to 1988 (Johansson et al., 2002).

The development of the demand for wood-fuel by the district heating can also explain the differences in the evolution of the adoption between the Central-Northern areas of the country, and the Southern regions of Kristianstad and Malmöhus. Although there is a large amount of agricultural land, in the South the development of adoption of willow was later than in the rest of the country: in 1990 there were less than 20 farmers growing willow in both regions combined, and by 1992, still less than 30. A possible explanation for this is the low demand for wood-fuel by district heating at the beginning of the decade, growing from less than 160 GWh in 1992 (District heating statistics) to more than 650 GWh in 1996. Also, this area has higher cereal productivity than the rest of the country, and is geographically more isolated from the rest of the agricultural areas where willow was planted, which contributes to a different diffusion of the adoption.

Besides the effects of the subsidies, the tax policies and the demand by the district heating plants, it must be pointed out the interesting high ratio of adoption in the Örebro region, one of the first regions where willow was planted commercially. In this area works Lantmännen Agroenergi, particularly involved in planting and marketing of willow varieties for biomass plantations, as wells as the development of the sector. The effects of show-hows, marketing campaigns and transfer of knowledge to the farmers would reveal fundamental tools for the diffusion and adoption of willow coppice.

The data shows that before 1991 there were already a significant number of willow growers, accounting for around 20% of the total aggregated figure in 1996. These first growers were concentrated especially in the Örebro region (which accounted for more than 40% of the initial growers). The model shows that at least 50% of the farmers that adopted willow after 1991 could be directly attributed as a consequence of the measures of the Swedish policy both in energy and agriculture. This figure can underestimate the total number since there were too few years to properly define the trend of adoption prior to the measures, and the lack of empirical experience in other countries. In addition, it is very difficult to make predictions out of the range of the data studied, since many variables related to the adoption are difficult to control and change over the time. For instance, a major factor affecting the adoption of willow after 1996 were the new regulations of the EU Common Agricultural Policy (Helby et al., 2004, 2006), which are not included in the model presented.

However, the model reveals that it is quite possible that the areas of the Central and Western Sweden were already close to their maximum number of adopters, under the conditions studied in this paper, and they would not have gained a significant number of new adopters even if the subsidies would not have been reduced in 1996, unless the demand for wood-fuels would have continued to increase. On the other hand, other areas of Sweden (particularly the Southern regions and the Eastern areas of the lake Mälaren) would possibly have increased the number of adopters in the following years if the policy framework would have been kept the same. The effect of the new power plants may have longer lasting effects on the adoption of willow by growers than assumed by the model; and future predictions would underestimate the maximum number of adopters to be reached (an example worthy of study would be in the municipality of Enköping, where there is a plant operating with new boilers adapted to willow wood chips, Mirck et al., 2005).

5. Conclusion

The specific combined effects of the policy measures in the adoption of willow plantations by Swedish farmers is a difficult issue to study, since there are many factors that are interrelated, and there is a high level of speculation in the final results. Besides its limitations, this study is a first step to future analyses of the adoption patterns of willow in countries willing to start a plantation schedule and it helps to analyse the effects of the market and the legislation on the development of the plantations. The models presented, and the scenarios derived from them, are a methodological tool to quantify and to analyse the effects of policy incentives. This can provide a deeper understanding of the success or failure of energy programmes and aid policy makers in achieving their goals.

Acknowledgements

Financial support for this project was provided by the North Karelia Regional Fund of the Finnish Cultural Foundation (Suomen Kulttuurirahasto). We are indebted to Gustav Melin and Stig Larsson at Agrobränsle AB (Lantmännen Agroenergi AB), for providing the data for the willow plantations, and to Charlotta Abrahamsson at Svensk Fjärrvärme AB. Our special thanks to Prof. Timo Pukkala for all his valuable cooperation and assistance with the modelling part. We also thank editor Nicky France and the anonymous reviewers for their valuable comments and to David Gritten for the linguistic revision of the manuscript.

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