A Spatial Panel Data Analysis of Tree Planting in the US South

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ABSTRACT

This study used panel data models with spatial error correlation to analyze private tree planting in the US South from 1955 to 2003. Controlling for statewide, fixed effects allows us to disentangle the effect of spatial interaction from that of state heterogeneity and omitted variables. The results show that there is significant spatial interdependence among the southern states in private tree planting. Harvest rates, softwood sawtimber price, income levels, cost of capital, and federal and state cost-share programs are important factors affecting nonindustrial private (nonindustrial private forestland [NIPF]) tree planting. Harvest rates, softwood sawtimber and pulpwood prices, and planting cost are important factors affecting forest industry (FI) tree planting. Finally, the Soil Bank Program has had substitution effects on southern FI tree planting and nonsubsidized NIPF tree planting.

Keywords: tree planting, private reforestation, cost-share program, panel data, spatial error correlation

Tree planting has long been a focus of public forest policy in the United States. Whether timber and nontimber forest products supply can meet future demand largely depends on today's tree planting activities. Historically, timberland in the US South received great attention because the region possesses the biological potential to produce more timber through intensive management than other parts of the country (Alig et al. 1999). Tree planting in the South is of particular interest as public forests in the Pacific Northwest are increasingly reserved for wildlife habitat, recreation, and other nontimber uses. In 2001, with only about 40% of timberland in the country, the South contributed 63% of the total national timber harvest (Smith et al. 2004).

Previous studies of tree planting have focused on nonindustrial private (NIPF) landowners, who own 71% of the timberland in the South, and forest industry (FI) firms, which own 18%. Unfortunately, some important findings in these studies appear inconsistent. Furthermore, the conceptual relationship between tree planting and some factors has not been developed explicitly. Third, most studies have used regional aggregates rather than more resolute, state-level, data. Thus, whether state characteristics such as urbanization and per capita income have anything to do with tree planting is unknown. Finally, traditional panel data analysis that uses state-level data does not consider the spatial interaction and thus may render biased estimates.

This study provides an analytical framework for tree planting and investigates the relationship between tree planting investment in the US South and a series of social and economic factors using state-level panel data with spatial interaction. The use of panel data is helpful for increasing the degrees of freedom, reducing the collinearity among explanatory variables, and correcting the bias generated by omitted variables and heterogeneity among cross-sectional units—hence improving the efficiency of econometric estimates. More importantly, by accounting for the spatial correlation associ-ated with our data, we test the independence assumption among cross-sectional units (states) (Kmenta 1971, p. 512). To our knowledge, this is the first empirical work in the tree planting or reforestation literature that accounts for spatial dependence. Our results are robust and may clarify some findings in the reforestation literature, especially with respect to the substitution effect of government subsidy programs.

Because public forests only account for a small portion (11%) of timberland in the region, only private tree planting is considered. The results may provide insights on private reforestation behavior and have implications for public policies aimed at increasing forest resources in the United States. Thirteen southern states are covered in this study [1]. The following section presents a review of the literature pertaining to tree planting in the US South, followed by an analytical framework of the tree planting model. The remaining sections present data, empirical results, and conclusions.

Tree Planting in the US South

Figure 1 shows the historical trend of private tree planting in the South by ownership from 1928 to 2003. Similar to the rest of the country, tree planting in the South can be roughly divided into three phases: initiation, acceleration, and steady growth (Zhang 2004) [2]. The initiation phase was from colonial times to 1945. Prior to the 1930s, only a few thousand acres of NIPF timberland were planted annually, mainly due to poor markets and to the lack of advanced technology, appropriate species, and public policy incentives. In the latter part of this phase, tree planting became financially attractive to some landowners, and the US government provided incentives, such as the Civilian Conservation Corps programs, to encourage tree planting. In 1945, private tree planting in the US South reached 46,904 acres.

The acceleration phase was approximately from 1946 to 1976 (Zhang 2004). Annual private tree planting accelerated due to
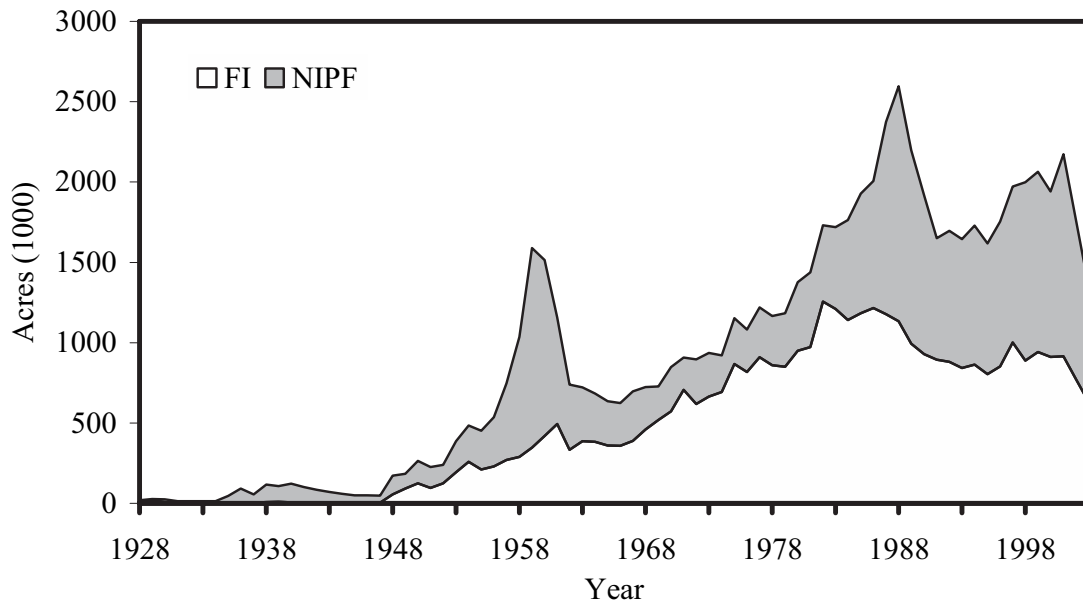
Figure 1. Private tree planting in the US South by ownership, 1928–2003. FI, forest industry; NIPF, nonindustrial private forestland.

strong market demand and favorable government policies. NIPF tree planting in the region increased from 44,461 acres in 1946 to 270,000 acres in 1976 at an annual growth rate of 6%. FI tree planting increased from 4,579 acres in 1946 to 820,000 acres in 1976 at an annual growth rate of 19%. Significant tree planting efforts are associated with federal incentive programs, including Soil Bank Program (SBP) from 1956 to 1963 and Agricultural Conservation Program (ACP) from 1936 to 1997. As shown in Figure 1, a tree planting spike in the late 1950s was associated with the SBP, designed as a tool for reducing agricultural surplus.

The steady growth phase started around 1977, although both NIPF and FI tree planting declined after 2001. During this period, annual private tree planting grew at a slower rate compared with that of the acceleration phase. Tree planting was flat for forest industry but grew 6% for NIPF landowners. Another tree planting spike occurred around 1988, associated with the Conservation Reserve Program (CRP) initiated in 1986. During this period, demand for timber grew steadily, and other favorable federal incentives, including the reforestation tax credit incentive, Stewardship Incentive Program (SIP), and forest incentives programs (FIPs), affected tree planting. FIP was designed solely for private forest management. Some states offered cost-share programs as well. The growth rate of nonsubsidized NIPF tree planting was around 8%. As of 2003, NIPF and FI tree planting in the region were 716,000 and 629,000 acres, respectively.

Many studies (e.g., de Steiguer 1984, Hardie and Parks 1991, Alig et al. 1999) address private tree planting or silvicultural investment behavior. Alig et al. (1990) provide an extensive review of studies on NIPF timber management. The difference in afforestation and reforestation behavior between NIPF landowners and forest industry landowners is widely recognized in these studies (Johansson and Löfgren 1985, Newman and Wear 1993).

Previous studies can be roughly classified into four categories based on their conceptual frameworks. Cohen (1983), Lee et al. (1992), and Kline et al. (2002) use a simple model derived from supply and demand relationship of the tree planting market and a reduced-form equation for estimation. One problem associated with this method is that some explanatory variables affect both supply and demand in different directions; thus, the theoretical relationship between tree planting and those variables is ambiguous. Other studies assume that both NIPF and industrial forests are managed on the basis of profit maximization. Newman and Wear (1993) indicate that both FI and NIPF landowners are profit-maximizing, although the hypothesis of an identical profit function for both is rejected. For industrial landowners, some studies assume that forests are managed on the basis of profit maximization of the whole vertically integrated business (Johansson and Löfgren 1985). In this case, stable wood supply is a major concern of forest management, including tree planting. This approach treats forest management in the same way as other industrial production without accounting for the long-term investment characteristics of tree planting.

Recently, a growing number of studies have been based on a utility maximization framework, especially for NIPF landowners. Utility is derived not only from income but also from the nonmarket amenity uses of the forest (e.g., Binkley 1981, Kuuluvainen et al. 1996). Kuuluvainen et al. (1996) show that single-objective forest owners are less responsive to stumpage prices than multiobjective owners who value both monetary and nonmonetary forest benefits. Binkley (1981) finds that farmers are more likely to harvest timber than nonfarmers. This method, based on individual preference, requires detailed micro-level data.

The most widely accepted approach is the Faustmann model, which assumes that private forests are managed on the basis of maximizing the expected net present value of future cash flow associated with the forest (e.g., Hyde 1980, Parks et al. 1998, Zhang and Flick 2001). Unlike the single-period profit maximization model, the present-value-maximizing model concerns multiple periods and implies efficient intertemporal allocation of resources. Unlike the plantation market approach, this method can generate a clear theoretical relationship between tree planting and explanatory variables. Hyde (1980) and Chang (1983) show that reforestation investment or tree planting is positively related to timber stumpage prices and the availability of government cost-share programs but negatively to planting costs and interest rates. In addition, tree planting is an

investment activity that is influenced by the availability of suitable land and by landowner characteristics, such as income, education, age, and so on.

Previous studies on private tree planting look mainly at landowners' response to market signals such as stumpage prices, reforestation costs, and interest rates. But findings from these studies are not consistent. For example, several studies (e.g., Chang 1983, Hyberg and Holthausen 1989, Kline et al. 2002) find that NIPF tree planting is highly related to either sawtimber or pulpwood stumpage price, or both, whereas other studies (e.g., Boyd 1984, Alig 1986, Royer and Moulton 1987) show a weak or nonexistent response to stumpage prices. As for FI tree planting, Kline et al. (2002) show that it is not responsive to stumpage prices, whereas Lee et al. (1992) find that it is positively related to sawtimber and pulpwood prices.

These mixed results also show up in the literature on reforestation costs, which are found to be negatively associated with NIPF tree planting by Brooks (1985), Royer and Moulton (1987) and Kline et al. (2002). Others (e.g., Lee et al. 1992, Kline et al. 2002), however, find no significant relationship between reforestation costs and FI tree planting. Finally, Lee et al. (1992) and Kline et al. (2002) show a negative relationship between interest rates and FI tree planting, and Kline et al. (2002) draw the same conclusion regarding NIPF reforestation. Cohen (1983), de Steiguer (1984), and Lee et al. (1992), on the other hand, show no significant effects of interest rates on NIPF tree planting.

The single consistent finding is that government cost-share programs and tax incentives have positive impacts on NIPF tree planting. However, findings on the existence and magnitude of a substitution effect of public funding for private investment in tree planting are inconclusive (Cohen 1983, de Steiguer 1984, Lee et al. 1992). Other factors influencing private tree planting include the availability of suitable land, landowner income, technical assistance, and land values (e.g., de Steiguer 1984, Lee et al. 1992, Kline et al. 2002). Generally, all these variables except land values have positive effects on NIPF tree planting.

The incongruent research findings related to private tree planting may be due in part to the type of data used. Some studies (e.g., Boyd 1984, Hardie and Parks 1996, Zhang and Mehmood 2001) are based on micro-level data generated from landowner surveys. Other studies (e.g., Skinner et al. 1990, Newman and Wear 1993, Kline et al. 2002) use data aggregated at the state, regional, or national level. Although using state-level data, de Steiguer (1984) estimates a private reforestation model using pooled regression under the assumption of homogeneity among states. Different states may have different economic and social characteristics that have an impact on private tree planting activities. A state-level panel data analysis is thus appropriate and desirable.

Recently, a growing number of studies have used a spatial econometric framework for empirical economic research (e.g., Anselin 1988, Benirschka and Binkley 1994, Bockstael 1996, Conley 1999, Irwin and Bockstael 2002). Some studies extended the application to panel data analysis (Case 1991, Kelejian and Robinson 1992, Case et al. 1993, Baltagi and Li 2004). Others test for spatial dependence in the context of panel data framework (Baltagi et al. 2003, Elhorst 2003).

Model and Data

Considering the advantages and disadvantages of different models and data available, we have used the Faustmann model as the conceptual basis for this analysis. Present value in this case is the expected total timber revenue minus the costs of silvicultural effort (or regeneration effort or tree planting used in this study). Since the present study is on the 13 US southern states, the fixed-effects model is preferred to the random-effects model. We assume that tree planting decision for all landowners in each state is subject to a vector of exogenous factors including stumpage prices, planting costs, capital costs, availability of government cost-share programs, landowner characteristics, availability of suitable lands, and other socioeconomic factors. The spatial interaction among states is incorporated via a spatial error model (Anselin and Bera 1998).

Let q_{ijt} (where state index $i = 1, \ldots, N$; ownership index $j = 1$ if FI or 2 if NIPF; time index $t = 1, \ldots, T$) be the area of tree planting in state i by ownership j at time t, and x_{ijt} be $k \times 1$ vector of variables influencing the regeneration efforts. T and N are total number of years and states, respectively. Then,

$$q_{ijt} = \alpha_{ij} + \mathbf{x}'_{ijt}\boldsymbol{\beta}_j + \varepsilon_{ijt}, \qquad (1)$$

where $\boldsymbol{\beta}_j$ is a $k \times 1$ vector of coefficients to be estimated, ε_{ijt} is a random disturbance term. α_{ij} is assumed to be fixed parameter for landowner j of state i and accounts for any state-specific effect not included in the regression equation. In vector form, Equation 1 is equivalent to

$$\mathbf{q}_{jt} = \boldsymbol{\alpha}_j + \mathbf{x}'_{jt}\boldsymbol{\beta}_j + \boldsymbol{\varepsilon}_{jt} \qquad (2)$$

with

$$\boldsymbol{\varepsilon}_{jt} = \lambda \mathbf{W}\boldsymbol{\varepsilon}_{jt} + \boldsymbol{\mu}_{jt}, \qquad (3)$$

where $\mathbf{q}'_j = (q_{1jt}, q_{2jt}, \ldots, q_{Njt})$, $\boldsymbol{\alpha}'_j = (\alpha_{1jt}, \alpha_{2jt}, \ldots, \alpha_{Njt})$, $\mathbf{x}'_{jt} = (x_{1jt}, x_{2jt}, \ldots, x_{Njt})$ and $\boldsymbol{\varepsilon}'_{jt} = (\varepsilon_{1jt}, \varepsilon_{2jt}, \ldots, \varepsilon_{Njt})$. λ is the spatial autocorrelation coefficient. $\mathbf{W}$ is an $N \times N$ weight matrix describing the neighborhood structure; its element w_{is} ($s = 1, \ldots, N$) equals 1 when state i and state s are contiguous and 0 otherwise. By convention, the diagonal elements of the spatial contiguity matrix $\mathbf{W}$ are zero. $\mathbf{W}$ also satisfies that $(\mathbf{I}_N - \lambda\mathbf{W})$ is nonsingular for all $|\lambda| < 1$. $\boldsymbol{\mu}'_{jt} = (\mu_{1jt}, \mu_{2jt}, \ldots, \mu_{Njt})$, where μ_{1jt} is i.i.d. over i and t and is assumed to be N(0, σ^2_μ).

Data for this study cover the 13 southern states from 1955 to 2003 [3]. Table 1 presents the definition and data sources of the explanatory variables used in this study. The dependent variable for all models is annual area of tree planting (in thousands of acres) by ownership (NIPF and FI) by state. The area includes the tree planting area enrolled in cost-share programs. The data are collected from the annual series of US tree planting reports by US Forest Service (1955–1999) and reforestation report by Georgia Forestry Commission (2000–2005). Stumpage price data are available only after 1955.

Because expected stumpage prices are difficult to identify, current softwood sawtimber and pulpwood stumpage prices are used as a proxy. They are expected to influence tree planting positively. Previous year harvest, a variable representing the availability of suitable land, is expected to be positively related to both FI and NIPF tree planting. Due to the lack of time-series forestland value data, the USDA Economic Research Service (1996) farmland values are used as a proxy. Effects of land value on tree planting are ambiguous. On one hand, land can be seen as an input in timber production. That means less tree planting when land price increases. Forestland, especially NIPF forestland, could then be converted into other uses. On the other hand, landowners may plant more trees to increase the capitalized value of their land. In particular, forest industry firms

Table 1. Variable definition and data sources.

Variables	Definition and data sources
Industrial harvest	Softwood harvest on FI timberlands in millions of cubic meter by state and year, estimated from yearly regional volume of softwood harvested by FI (Adams et al. 1988, Haynes 2003) weighted by net volume of softwood growing stock on FI timberland by state (Smith et al. 2004). Missing data are filled with interpolation.
Nonindustrial harvest	Softwood harvest on NIPF timberlands in millions of cubic meter by state and year, estimated from yearly regional volume of softwood harvested by NIPF (Adams et al. 1988, Haynes 2003) weighted by net volume of softwood growing stock on NIPF timberland by state (Smith et al. 2004). Missing data are filled with interpolation.
Land value	Farmland value per acre in dollars (1984) by state and year (in Scribner log rule), from the USDA Economic Research Service (1996). Recent data are estimated by trend.
Softwood sawtimber price	Stumpage prices of softwood sawtimber in $/mbf (in Scribner log rule) by state and year, deflated by PPI (Producer Price Index 1984), and data for 1977–2003 are from Timber Mart-South (Norris 1977–2003), and 1955–1976 subregional data from Ulrich (1989) are used as approximation.
Softwood pulpwood price	Stumpage prices of softwood pulpwood in $/standard cord by state and year, deflated by PPI (1984 dollars), data for 1977–2005 are from Timber Mart-South (Norris 1977–2003), and 1955–1976 subregional data from Ulrich (1989) are used as approximation.
Planting cost	Regional average cost of hand and machine planting in dollars (1984) per acre, from Dubois et al. (1999) and Kline et al. (2002).
Cost of capital	Average annual real rate (nominal rate minus inflation) of return in percent on bank prime loan, from the US Federal Reserve Board (2007).
MSA population	Metropolitan Statistical Area population in millions by state, from US Census Bureau (1955–2003).
Per capita income	Real per capita personal income in thousand dollars (1984 dollars) by state and year, from USDC Bureau of Economic Analysis (2007).
ACP cost-shared area	Annual ACP tree planting area in thousand acres by state, from Agricultural Statistics by the USDAC (1955–2003).
CRP cost-shared area	Annual CRP tree planting area in thousand acres by state, from USDA Farm Service Agency (2003).
FIP cost-shared area	Annual FIP tree planting area in thousand acres by state, from USDAC (1955–2003).
SBP cost-shared area	Annual SBP tree planting area in thousand acres by state, from USDA Commodity Stabilization Service and Agricultural Conservation Program Service (1957–1972).
State cost-share availability	Dummy: 1 if there is available state tree-planting cost-share program in that year, 0 otherwise.

may plant more trees to ensure timber supply to their mills (and thus protect their investment) if NIPF landowners plant fewer trees due to increase in land value. Real prime interest rate, used as an approximation of cost of capital, is expected to have a negative influence on tree planting. Planting costs are expected to have a negative impact on tree planting.

Four major federal cost-share programs (SBP, CRP, FIP, and ACP) and the availability of state cost-share programs are used to estimate the effect of government aid on private tree planting. These programs are expected to have a positive impact on NIPF tree planting. However, their impacts on FI tree planting and nonsubsidized NIPF tree planting are ambiguous. Per capita income—an approximation of NIPF landowner income—is expected to be positively related to NIPF tree planting for two reasons. First, high income makes planting expenses more affordable to NIPF landowners. Second, landowners may value forests more when their wealth increases. As a result, they plant more trees on their land.

Metropolitan population can be used as an indicator of urbanization (Shi et al. 1997). Wear and Greis (2002) and Kline et al. (2004) indicate that urbanization reduces land for forest uses, which in turn increases the opportunity cost of reforestation. As defined by the US Office of Management and Budget (2000), metropolitan areas cover 258 metropolitan statistical areas and 18 consolidated metropolitan areas in the United States. One of the concerns is that urbanization pressure may have already been capitalized into the land value, which may cause multicollinearity for estimation. However, the Pearson correlation coefficient of 0.24 and Pearson partial coefficient of 0.17 (after controlling effects of other variables) suggest that correlation between these two variables is not a problem. The variable representing metropolitan population is expected to have a negative impact on private tree planting as forest lands are converted to urban use. Meanwhile, a time-trend variable is included to account for the long-term effect due to the length of the study period.

Table 2. Estimates of the FI tree planting models.

Variable	Model I	Model II
Industrial harvest	0.13[a]	0.09[a]
Land value	−0.01[b]	−0.01
Softwood sawtimber price	0.16[a]	0.15[a]
Softwood pulpwood price	0.76[a]	0.82[a]
Planting cost	−0.19[a]	−0.07
MSA population	−0.86	−0.61
Interest rate	2.35[a]	1.68[a]
Time trend	0.84[a]	0.77[a]
ACP cost-shared acres		0.46[a]
CRP cost-shared acres		0.21[a]
FIP cost-shared acres		1.35[a]
SBP cost-shared acres		−0.28[a]
State cost-share availability		1.35
Spatial autocorrelation	0.39[a]	0.27[a]
R^2	0.74	0.76
Adjusted R^2	0.73	0.75
LM test for spatial correlation in residuals	150.57[a]	72.1[a]
Moran I-test	12.60[a]	8.91[a]

[a] Significant at the 1% level.
[b] Significant at the 10% level.

Results

Tree planting models are developed for FI and NIPF landowners separately. For FI, an alternative model with government cost-share programs is developed to account for the impact of government assistance. A nonsubsidized NIPF tree planting model is also estimated to see whether there are substitution effects for government programs. In total, there are four models. Following Elhorst (2003), the models are tested for spatial effects and estimated using maximum likelihood methods.

Industrial Tree Planting

Table 2 shows the estimation results for FI tree planting. Models I and II have adjusted R^2 of 0.73 and 0.75, respectively, suggesting overall good fit of the models. The λ estimates are 0.39 for Model I and 0.27 for Model II. The Lagrange multiplier (LM) test and

Moran I-test are used to test the presence of residual spatial auto-correlation ($\lambda = 0$). Both tests are highly significant at the 1% level for both models and indicate significant spatial dependence. This implies that FI tree planting behaviors are correlated over space, and estimation errors (misspecification) may arise if the spatial dependence among states is neglected.

For each model, the relationships between softwood sawtimber and pulpwood prices and FI tree planting are significant and positive, as expected. Unlike the results of Kline et al. (2002), this result indicates that FI tree planting does respond to price signals. Consistent with earlier findings, softwood harvest is found to have a positive impact on FI tree planting. Unlike the results of Lee et al. (1992) and Kline et al. (2002), land prices are negatively significant for Model I. This implies that FI firms plant fewer trees when land prices increase.

Model I also suggests that plantation costs have a significant negative impact on FI tree planting. However, the coefficients of capital costs are positive, contrary to our expectation. Both models have coefficients for the time trend that are significant and positively related to FI tree planting. This suggests a general increasing trend of tree planting over the study period after controlling other factors. The coefficients for urbanization are not significantly different from zero in both models.

The third column of Table 2 shows the estimates of Model II for FI tree planting by accounting for the effects of government cost-share programs. The coefficients of land values and planting costs are not significant. The effects of most factors other than these programs are essentially unchanged from Model I. Three federal cost-share programs (CRP, FIP, and ACP) show a significant and positive relationship with FI tree planting. The SBP, however, does not. In other words, cost-share programs aimed at encouraging NIPF landowners to plant more trees do not discourage FI tree planting. Both Lee et al. (1992) and Kline et al. (2002) find a positive relationship between CRP acreage and FI tree planting. Lee et al. (1992) suggest that some important factors might be missing, whereas Kline et al. (2002) explain this as a coincidence. Substitution effects associated with SBP are evident in the present study. The coefficient of the state cost-share program variable is not significantly different from zero. This may be due to the fact that the annual enrollment acreage under state programs is relatively small compared with that of federal cost-share programs.

Nonindustrial Private Forest Tree Planting

Table 3 presents the estimation results for NIPF tree planting. Similar to FI tree planting models, significant values for the LM test and Moran test suggest the presence of spatial correlation among southern states in tree planting behaviors. Both models fit well.

The second column of Table 3 shows the results for the model including acres enrolled in government programs (Model I). Softwood harvest is again shown to be significant and positive with respect to NIPF tree planting. Softwood sawtimber stumpage price also has a significantly positive impact on NIPF tree planting. However, softwood pulpwood price is not significant. In contrast to some previous findings that NIPF is insensitive to market signals, our results suggest that NIPF landowners plant more trees if sawtimber stumpage prices increase. As expected, the cost of capital has a negative impact on NIPF tree planting. Consistent with previous studies, income plays a significantly positive role in NIPF tree plantation. All four federal cost-share programs are significant and positively related to NIPF tree planting. Contrary to Kline et al. (2002),

Table 3. Estimates of the NIPF tree planting models.

Variable	Model I	Model II
Nonindustrial harvest	0.07[a]	0.07[a]
Land value	0.00	0.00
Softwood sawtimber price	0.24[a]	0.24[a]
Softwood pulpwood price	0.29	0.29
Planting cost	−0.07	−0.08
MSA population	−0.88	−0.76
Interest rate	−1.01[b]	−1.02[b]
Time trend	−0.93[a]	−0.96[a]
Per capita income	4.38[a]	4.41[a]
ACP cost-shared acres	2.04[a]	1.01[a]
CRP cost-shared acres	1.15[a]	0.18[b]
FIP cost-shared acres	0.82[a]	−0.21
SBP cost-shared acres	0.69[a]	−0.23[b]
State cost-share availability	6.26[c]	6.63[b]
Spatial autocorrelation	0.23[a]	0.23[a]
R^2	0.79	0.60
Adjusted R^2	0.78	0.58
LM test for spatial correlation in residuals	14.26[a]	13.42[a]
Moran I-test	4.19[a]	4.07[a]

[a] Significant at the 1% level.
[b] Significant at the 5% level.
[c] Significant at the 10% level.

this study shows that the FIP, like other cost-share programs, has a positive impact on NIPF tree planting. Unlike the FI models, state cost-share programs are significant and positively related to NIPF tree planting.

In contrast to the FI models, there is a significantly negative trend over time for NIPF tree planting. Alternatively, planting costs, land values and urbanization are not significantly different from zero.

The third column of Table 3 shows the results of the nonsubsidized NIPF tree planting model (Model II). ACP, CRP, and state cost-share programs have positive effects on nonsubsidized NIPF tree planting, which suggests the programs contribute to an increase in non-cost-shared plantations. However, the negative coefficient on SBP suggests the presence of substitution effects for SBP on nonsubsidized NIPF tree planting. These results are different from those of Lee et al. (1992), in which only CRP had significant positive effects. The reason may lie in the data used (this analysis has a longer study period and is by state, whereas their analysis is based on aggregate data for the South) and the involvement of spatial interaction among states. The coefficients of metropolitan population are not significantly different from zero, indicating that urbanization pressure might not have an impact on NIPF tree planting.

A Comparison of FI and NIPF Tree Planting

It is interesting to note that FI tree planting is more responsive to timber harvesting than NIPF tree planting by a ratio of 2 to 1. This means that more industrial timber lands are reforested after timber harvesting than nonindustrial lands. FI tree planting is more responsive to pulpwood prices than NIPF tree planting, whereas NIPF tree planting is more responsive to sawtimber prices than FI tree planting. This may be explained by the generally accepted fact that trees on NIPF lands have longer rotations than those on industrial forest lands. As a result, NIPF tree planting decisions are more sensitive to sawtimber prices than pulpwood prices.

Discussion and Conclusions

This study investigated the determinants of private tree planting in the US South by using spatial panel data analysis techniques. By

controlling spatial autocorrelation effects and state-specific fixed effects, we are able to get more accurate estimates of the impacts of other social-economic factors on private tree planting behaviors. All models in the present study show the presence of significant spatial interaction among the southern states, suggesting that regional tree planting studies should account for spatial effects.

Most of the explanatory variables have the expected signs and are significant. FI and NIPF tree planting were positively related to previous-year harvest. Both NIPF and FI tree planting were responsive to market signals, especially softwood sawtimber price. Urbanization pressure had little impact on private tree planting at the state level. As for interest rates, the results imply that they had negative impacts on NIPF tree planting. NIPF landowners with higher income were inclined to plant more trees. FI tree planting was negatively related to planting costs. On the other hand, the magnitude of the response was quite different. FI tree planting was more responsive to timber harvesting and pulpwood price than NIPF tree planting by a ratio of 2–3 to 1.

The results also suggest that SBP might have substitution effects on southern FI tree planting and nonsubsidized NIPF tree planting. On the other hand, ACP and CRP are shown to have positive impacts on nonsubsidized NIPF tree planting and FI tree planting. FIP has a positive impact on FI tree planting but no significant impact on NIPF tree planting. State cost-share programs have positive impacts on NIPF tree planting. These results may help clarify some empirical findings with respect to substitution effect of government subsidy programs—when the subsidy is large and given out in a short time, it may have a substitution effect and distort the market; otherwise, economics dictate private tree planting activities in the United States.

Like other studies, this study uses current stumpage prices as a proxy for expected prices. Problems arise because current prices are likely correlated with recent harvest. More appropriate estimates of expected prices are desirable. Further study can also be done using more state-specific data for planting costs and cost of capital and using forestland value instead of farmland value.

Endnotes

[1] Alabama, Arkansas, Florida, Georgia, Kentucky, Louisiana, Mississippi, Oklahoma, North Carolina, South Carolina, Tennessee, Texas, and Virginia.
[2] This division only applies to total private tree planting activity, which may not be appropriate for just NIPF or FI tree planting. For example, the period of acceleration runs from 1948 to 1983 for forest industry, and from 1948 to 1960 and from 1978 to 1998 for NIPF tree plantations.
[3] Since complete FI tree planting information for 2004 and 2005 is not available, we only use the data up to 2003.

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