Empirical Studies of Non Industrial Private Forest Management: A Review and Synthesis

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ABSTRACT

Forest policies and management increasingly rely on economic models to explain behaviors of landowners and to project forest outputs, inventories, and land use. However, it is unclear whether the existing econometric models offer general conclusions concerning NIPF management or whether the existing results are model and/or data specific. In this paper, we systematically review the empirical literature on NIPF management and confirm four primary factors as determinants of management: market drivers, policy variables, owner characteristics, and plot/resource conditions. We rely on the most basic form of meta-analysis, vote counting, to combine information from many studies to produce more general knowledge concerning the key determinants of reforestation and silvicultural treatments. We find that targeted policies and market prices are the most commonly studied in reforestation models, a modeling choice that is somewhat justified by their statistical influence. We conclude with some methodological and policy suggestions.

1.0 INTRODUCTION: MICROECONOMIC MODELS OF FOREST MANAGEMENT

Forest landscapes in the US are shaped primarily by biological and environmental conditions, land and timber markets, and public policies. Because each of these forces is inextricably linked to the socio-economic system, the links between forest conditions and human activities must be adequately captured by modeling systems that can project forest landscapes.[1] Microeconomic models are key elements of such modeling systems because they explain landowner behavior and management based on market, owner, policy and resource characteristics and project forest outputs, inventories, and land use. Management practices such as reforestation and silvicultural treatments are an important set of landowner behaviors of interest. However, it is unclear whether the existing econometric models offer general conclusions concerning NIPF management or whether the existing results are model and/or data specific. In this paper, we systematically review the empirical literature on NIPF management and identify the determinants of forest management within an economic framework. We rely on the most basic form of meta-analysis, vote counting, to combine information from many studies to produce more general knowledge concerning the key determinants of reforestation and silvicultural treatments. Given that forests are primarily owned by private entities in the US south, this type of information can help assess future forest landscapes and develop sound forest policy.

In sections 2 and 3, we briefly describe reforestation and silvicultural treatments in the U.S and our meta-analysis methods. In section 4, we review the literature and report results of a simple vote-count based meta-analysis. Finally, we conclude in section 5 by discussing methodological approaches for the research community and the main policy implication.

2.0 TREE PLANTING AND SILVICULTURAL TREATMENTS IN THE U.S.

This section summarizes recent levels of tree planting and silvicultural investments for NIPF owners, the forest industry, and public lands across three regions of the U.S., including the South.[2] Over the last several decades, there has been a substantial increase in U.S. timber production, with much of the increase concentrated in the South, a region that has a relatively large share of timberland controlled by NIPF landowners (69 percent) compared with the U.S. overall (58 percent) (USDA Forest Service, 2001; Smith et al., 2001). The South's share of total U.S. wood production has increased from about 40 percent in 1962 to more than 58 percent in 1997 (USDA Forest Service, 2001). While a large share of timber has historically been produced on NIPF lands, the combination of increasing demand for wood products and recent reductions in

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[1] Although the links between biological or environmental factors and human activities may be less obvious than for the other forces, there are important connections. For example, while pathogens, insects, fires, and mortality are natural components of forested ecosystems, land use and management can alter their effects. In addition, anthropogenic air pollutants may affect forest health (USDA Forest Service, 2001).

[2] The states included in the South region are Alabama, Arkansas, Florida, Georgia, Kentucky, Louisiana, Mississippi, North Carolina, Oklahoma, South Carolina, Tennessee, Texas, and Virginia.

timber harvesting on public lands has focused attention on the potential for NIPF lands to supply an even larger share of timber in the future. At the same time, upward trends in the South's population along with changes in other demographic variables are leading to increasing scarcity of amenity services associated with standing forests, especially in urban areas (Mansfield et al., 2002).

As a result, there is great interest in predicting the behavior of NIPF owners in response to changes in forest conditions and public policies, including their decisions regarding forest management behaviors. Following timber harvest, forestland owners can either expend resources to establish and maintain plantations, allow forests to evolve largely through natural processes, or convert forests to alternative land uses (e.g., agriculture or developed uses).[3] Land allocation between forestry and other uses is dependent on natural factors affecting forest growth (e.g., climate, land quality), market factors such as the expected rates of return to alternative land uses, and the value of nonmarket amenities associated with each potential land use, among other influences. In addition, establishing and maintaining a plantation increases timber productivity, but is more costly than allowing natural growth patterns.

The harvesting objective appears to have motivated investment in forest management activities such as active replanting, thinning, fertilization, insecticide use, and weed control in recent years. NIPF owners planted over 1.2 million acres of trees in fiscal year (FY) 1998, accounting for just under half of the total acreage planted in the U.S. (Moulton and Hernandez, 2000). In the South, NIPF landowners account for the largest share of both tree planting and silvicultural investments. Thus, it is important to study the behavior of NIPF landowners with respect to management behaviors to adequately project future timber supplies and forest landscapes.

Tree planting in the United States has been on a long term upward trend, increasing from about 0.14 million acres in 1930 to approximately 2.6 million acres in FY 1998. Between 1930 and 1998, there have been three major peaks of tree planting activity, all of which were associated with major Federal programs. The Civilian Conservation Corps (CCC) planted 2.3 million acres of land to trees between the mid-1930s and mid-1940s as part of a program that arose during the Great Depression to provide employment opportunities. In addition, the Soil Bank program planted 2.2 million acres of private crop lands to trees from 1956 to 1961 and the Conservation Reserve Program (CRP) has planted trees on 2.8 million acres of highly erodible cropland, mostly during the late 1980s. During the 1990s, tree planting has been on a slight downward trend, with the exception of NIPF lands (Moulton and Hernandez, 2000).

As shown in Table 1, private landowners accounted for 89.7 percent of all tree planting in the U.S. in 1998, with NIPF landowners planting 47.9 percent of the total U.S. acreage and the forest

[3]The term "plantation" refers to wooded areas where the trees have been planted with the intention of producing timber and which are often actively managed through the use of fertilizers, herbicides, pesticides, thinning of competing vegetation, and other treatments. In the South, the majority of plantations are planted with fast-growing species of pine trees.

industry planting 41.7 percent of total U.S. acreage. Tree planting in national forests fell to its lowest level since 1960, constituting only 5.6 percent of acreage planted in the U.S. This trend reflects national forest policy decisions to reduce timber harvests on federal lands, which reduces the area subject to post-harvest regeneration. Overall, the Federal government planted 7.2 percent of the total U.S. acreage of trees, while state and local governments accounted for the remaining 3.1 percent of acreage planted (Moulton and Hernandez, 2000). However, these proportions differ substantially between regions of the U.S. (see Table 2). In the South, 96.7 percent of trees are planted by private landowners, with NIPF owners accounting for 53.7 percent of trees planted in this region. In contrast, the West had only 60.6 percent of trees planted by private landowners, with NIPF landowners accounting for only 18.2 percent of trees planted in this region.[4] The North has a distribution that includes much less forest industry planting than either of the other two regions.[5] In the North, 75.9 percent of trees were planted by private landowners in FY 1998 and NIPF owners accounted for 60.2 percent of all trees planted in the region. The differences in distribution of tree planting across these groups between regions suggests that the recent shift in production towards the South may increase the importance of NIPF landowners in ensuring sustainable levels of production of forest products.

The South is characterized by substantial tree planting. Nine of the eleven states that planted more than 100,000 acres of trees in FY 1998 are in the South and the region planted 78.7 percent of all trees planted in the U.S. The West ranked second with 17.0 percent of the U.S. total, followed by the North, which accounts for only 4.3 percent of total planting. However, despite its large share of tree planting, the South ranks far behind the West in mid-rotation timber stand improvement. Silvicultural improvement was reported for about 2.4 million acres in the U.S. in FY 1998, of which 79.3 percent was in the West, 14.0 percent was in the South, and 6.7 percent was in the North. As shown in Table 3, industrial forest owners stand out as the single dominant group conducting these improvements, accounting for 68.0 percent of the total U.S. acreage with silvicultural improvements in FY 1998. The national forests were second with 12.6 percent of acreage. While NIPF owners accounted for the highest percentage of tree planting nationwide, they completed only 11.8 percent of silvicultural improvements. This is despite the fact that data collected by the USDA Forest Service indicates that many of these lands could benefit from such activities (Moulton and Hernandez, 2000). Interestingly, the distribution of silvicultural stand improvements across ownership categories is quite similar for the South and North regions, but these regions differ sharply from the West. NIPF owners actually account for the largest percentage of silvicultural improvements of any ownership category in the South and North, but conduct only 2.6 percent of timber stand improvements in the West (see Table 4).

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[4]The states included in the West region are Alaska, Arizona, California, Colorado, Hawaii, Idaho, Kansas, Montana, Nebraska, Nevada, New Mexico, North Dakota, Oregon, South Dakota, Utah, Washington, and Wyoming.

[5]The states included in the North region are Connecticut, Delaware, Illinois, Indiana, Iowa, Maine, Maryland, Massachusetts, Michigan, Minnesota, Missouri, New Hampshire, New Jersey, New York, Ohio, Pennsylvania, Rhode Island, Vermont, West Virginia, and Wisconsin.

These data provide anecdotal evidence that NIPF owners may behave differently from forest industry landowners. For instance, NIPF owners account for disproportionately small proportions of both tree planting and silvicultural improvements relative to their share of private acreage. In the South, NIPF owners control about 79 percent of the total private timberland acreage, while the forest industry owns the other 21 percent (USDA Forest Service, 2001).[6] However, NIPF owners account for only about 56 percent of both tree planting and silvicultural improvements conducted by private owners in the region despite controlling about 79 percent of private timberland acreage. Nationally, private tree planting and silvicultural improvement is even more skewed towards forest industry. Approximately 81 percent of private timberland acreage in the U.S. is owned by NIPF landowners (Smith et al., 2001), but only about 53 percent of tree planting and 15 percent of silvicultural improvements conducted by private owners are on NIPF lands. As a larger percentage of timber production comes from NIPF landowners, it is vital to understand the factors influencing the planting and timber management decisions for NIPF landowners in order to accurately project the condition of forest resources and to efficiently structure forest policies.

3.0 THE ROLE OF LITERATURE REVIEWS

There is a small but growing empirical literature surrounding the forest management practices of NIPF landowners. This is driven by the combination of increasing forest product market share for NIPF landowners and the complexity of explaining their behavior. In general, it is difficult, if not inappropriate, to generalize from individual studies of forest management due to limitations of (a) populations sampled, (b) time dimension considered, (c) factors and variables included, and (d) variation in policy variables. In the context of NIPF management, a systematic literature review can help identify the most relevant factors for explaining behavior and inform the development of future empirical models.

A potentially important improvement over conventional literature reviews is to use meta-analysis to quantitatively summarize findings across studies. In its most general form, meta-analysis offers a set of quantitative techniques that permit synthesizing results of many types of research, including opinion surveys, correlation studies, experimental and quasi-experimental studies, and regression analyses. Here we investigate consistency across different NIPF management studies to evaluate whether the studies are simply generating random noise concerning the determinants of active management. In this method, the investigator gathers all the studies relevant to an issue and then constructs one or more indicators of the relationships under investigation from each study. In general, study level data can be analyzed like any other data, permitting a wide variety of quantitative methods.

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[6] About 201 million out of 215 million acres of forest land in the South are classified as timberland and approximately 180 million acres of this timberland (89 percent) is privately owned (USDA Forest Service, 2001).

The simplest of the meta-analytical methods is the vote-counting method, in which the investigator categorizes findings (*e.g.* statistical correlation with reforestation) as significantly positive, significantly negative, or not significant for each variable (*e.g.* timber prices). The category with the most entries is then considered the best representation of the relationship between the dependent variable and each of the explanatory variables of interest. For each variable, each study gets to cast a 'vote' in support of one of the three types of relationship – positive, negative, and insignificant. By counting up the number of votes across the studies, we can 'declare a winner' and identify a general relationship for that specific variable. As such, vote counting provides a useful starting point for a systematic assessment of multiple studies.

In order to conduct our literature review, we searched the databases Agricola, Biological Abstracts, and Scientific Citation for publications from the last 20 years that included econometric estimates of the influence of factors affecting reforestation and/or silvicultural treatment decisions. For the purposes of our review, silvicultural treatment is defined as thinning, cleaning, release, fertilizer use, insecticide use, weed control, and other forms of timber stand improvement. In addition, electronic archives of 10 of the professional journals that most commonly publish research of the type being reviewed were searched for similar articles.[7] The articles were then collected and screened based on empirical content and relevance to the review. Based on the criteria of (a) statistical analysis of landowner data and (b) focus on forest management, we limit our comparative analysis to 16 studies that estimate econometric models of reforestation and 5 studies that estimate econometric models of silvicultural treatments.[8] Table 5 summarizes some of the characteristics of these research studies, including author(s), the region being analyzed, the type of data used (e.g., cross-sectional), the dependent variable(s), and the method used for estimation.

The majority of the studies were conducted in the U.S., predominantly in the South. Most rely on surveys of landowners, often in conjunction with secondary data on resource characteristics from, e.g., the USDA Forest Service Forest Inventory and Analysis (FIA). In addition, financial and economic statistics are typically included as explanatory variables in the econometric models estimated. Each of the models used, with the exception of Newman and Wear (1993), are reduced form regressions, rather than models reflecting an explicit underlying theoretical structure (profit and/or utility maximization).[9] Many of the models estimated are binary choice models (e.g., probit, logit) of the reforestation or silvicultural investment. These models estimate the influence of each independent variable on the probability that the activity being modeled will take place. In addition, there are a few studies that rely on ordinary least squares (OLS)

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[7]These journals are: American Journal of Agricultural Economics, Forest Ecology and Management, Forest Policy and Economics, Forest Science, Journal of Environmental Economics and Management, Journal of Forest Economics, Journal of Forestry, Land Economics, Northern Journal of Applied Forestry, and Southern Journal of Applied Forestry.

[8]Two of the papers (Löyland et al. (1995) and Zhang and Flick (2001)) provide the results of econometric models for both reforestation and silvicultural treatments. Thus, there are 19 different papers included in the review.

[9]Newman and Wear (1993) estimate a restricted profit function using a Generalized Leontief functional form.

regressions, which estimate the influence of the independent variables on the amount of the activity that takes place (usually in terms of acreage).

We proceed by using vote counting meta-analyses of NIPF reforestation and silvicultural investment. Often meta-analyses employ more rigorous techniques to derive cross-study quantitative estimates of the magnitude of some relationship (e.g., a price elasticity of demand). However, we are looking more broadly at the relationship between types of variables and the propensity to engage in types of forest management, which makes the vote counting method most appropriate. Moreover, we are restricted from estimating the magnitude of effects by the discrete choice nature of our dependent variable in most studies (e.g., either reforest or not) and the lack of details on marginal probability of forest management activities with respect to changes in the explanatory variables.

To implement this procedure, we define broad categories of factors that influence the management decision and identify several variables within each category, applying the vote counting method to each. That is, for all studies included in the meta-analysis, we determine for each variable of interest whether the variable was included in the study and, if so, whether there was a statistically significant positive or negative relationship with the forest management decision.[10] These results are then summarized by calculating the percentage of studies that included each variable, the percentage of studies that found a statistically significant effect for a variable out of all studies that included the variable in their empirical analysis, and the percentage of studies that found a statistically significant effect out of all studies.

4.0 COUNTING VOTES ON NIPF MANAGEMENT

Many different independent variables have been incorporated in models of NIPF investment and management. Through our review of the available body of empirical research, we find there are four primary sets of factors used to explain management decisions: market drivers, policy variables, owner characteristics and plot/resource conditions. Each is briefly described below.

Before we turn to these categories of variables, consider two caveats. First, these are not mutually exclusive categories because of complementarity and/or correlation between categories. To some extent, these interrelationships arise because we are using ‘economic lenses’ (or an economic framework), which categorize all non-economic elements (physical, institutional, etc.) in terms of economic incentives, constraints, or expectations and integrate them within one framework. That is, we can view all non-economic drivers as implicit economic determinants of forest management. Second, in a world of limited research resources and less than exhaustive lists of explanatory variables, we can see how investigators may have employed the same variable to proxy for different underlying factors. Thus, we can always debate whether a specific variable

[10]Statistical significance, as defined in this study, refers to significance at the 10 percent level (*i.e.* a null hypothesis (no relationship) with a probability value less than 0.1).

accurately proxies specific relationships and factors, and the reader may interpret these proxies differently.

- *Market drivers* include factors that explicitly alter the costs and/or benefits of forestry such as output prices, tree planting costs, and the returns to alternative investments. An increase in output price, reduction in planting costs, or increase in the return to forestry relative to agriculture and other alternative land uses will tend to increase investments in forestry.
- *Policy variables* are those factors that depend on policies that influence the forestry investment decision. Typically, these policies are Federal, state, or local programs designed to alter the allocation of land to forestry and/or the allocation of resources to reforestation and silvicultural investment. Government policies that lower the costs of investments in forestry (e.g., tax incentives, cost sharing, and technical assistance) will tend to increase those investments.
- *Owner characteristics* attempt to measure the preferences and resources of the NIPF landowner. Typically, landowner specific preferences are difficult to measure explicitly and are therefore proxied by socio-demographic information such as age, education, and social status. NIPF landowners' income is often used as a measure of their available resources for investment in forestry. Thus, higher income will tend to increase the probability of investment in forestry activities.
- *Plot/resource conditions* relate to influences on the physical production process associated with forestry production such as soil quality, slope of land, and plot size. The better the conditions for forestry, the greater the incentive to engage in forestry production, other things being equal.

For each study, we reviewed the text and tables to identify variables that fit into the four categories of management influences identified above. We identified several variables within each of these broad categories and applied the vote counting method to each. The results of this analysis are presented below for reforestation and silvicultural treatments.

4.1 A Vote Count of Reforestation

Table 6 summarizes the vote counting results for the empirical reforestation literature. For each study, the table shows whether there was a statistically significant positive (+) or negative (-) relationship between the relevant variables and reforestation. Variables that were included in a study but were not significant are denoted by a "0". If a study did not include a particular variable in their reported results, the corresponding table entry was left blank. At the bottom of the table are summary statistics indicating the total number and share of studies that include each variable and how often the variable is statistically significant. The row "Percent Included" shows the percentage of studies including each variable. Market drivers is the category of variables most often included in models of reforestation (88%), followed by policy variables (81%), owner characteristics (63%), and plot/resource conditions (31%). Among individual variables, the most commonly included are sawtimber prices and government cost sharing, present in 75% and 81% of the empirical models, respectively.

Although the percentage of studies in which a variable or category of variables is present in an indication of its popularity (and presumably researchers' expectations of the most important influences), this measure is not necessarily a good means of assessing influence on the reforestation decision. For a better assessment, consider the percentage of studies that included a particular variable or category that found it had a significant effect. This percentage is included in Table 6 in the row labeled "Percent Significant (Included Studies)". Using this measure, the ordering of the four primary sets of factors in terms of their likelihood of having a statistically significant effect becomes: policy variables (92%), market drivers (86%), plot/resource conditions (60%), and owner characteristics (50%). Of course, statistical significance is part of the story; we discuss constraints on analyzing the magnitude of impact in Section 5. As far as the direction of these effects, there is very little disagreement among the reforestation studies analyzed. The long-term interest rate is the only variable for which there is an inconsistency between studies as to the sign of its influence (considering only statistically significant estimates).

Among individual variables, short-term interest rates and agricultural crop price indices are statistically significant in every model that includes them. In addition, government cost sharing is significant in every study that examines whether it has an effect on reforestation overall (12 of 13 studies that include it). The only study that does not find a statistically significant effect is de Steigeur (1984), but that study considered how government cost share can crowd out private investment rather than the impact on total reforestation. Other variables that are found to be statistically significant in over half of the models that included them are technical assistance (80%), planting costs (67%), site quality (67%), plot size (60%), and income (56%). Although both sawtimber price and pulpwood price are significant 50% of the time, price is significant in 62% of studies because two studies include both prices and find only one of them to be statistically significant. At the other end of the spectrum, owner age and owner occupation are not significant in any of the reforestation studies.

Given the predisposition in the literature towards variable significance, researchers tend to focus on model specifications that find significance and to include variables with significant coefficients in their analyses. It is quite likely that variables that were not statistically significant were dropped from analyses during the exploratory phase in some cases and were not included in the final results. As a result, the probability that the studies report a statistically significant result is conditional upon the study including the variable in the analysis. The bottom row of Table 6, "Percent Significant (All Studies)", shows the percentage of the 16 reforestation studies that found significant effects. This measure reflects a very conservative assumption that all studies that did not include a variable in their reported results dropped the variable from their analyses because they found it was not significant. We discuss the results in more detail for each category below.

4.1.1 Market Drivers

The market drivers that are most commonly included in this research are timber prices, planting costs, and interest rates. NIPF owners' responses to market signals can be viewed in terms of responses to these variables. One of the variables generally expected to be most important in determining the behavior of suppliers is output price. While sawtimber and pulpwood prices would both be expected to have a significant positive effect on reforestation, the empirical results are somewhat mixed. The effects of price on reforestation are generally positive and are statistically significant in 62% of the studies that include price, but tend to be fairly small in magnitude.[11] Generally, investigators include either the sawtimber price or the pulpwood price, but not both, due to strong correlation between those prices. Among those studies that included both prices, Royer (1987) did not find sawtimber prices to be significant, but did find significant effects of pulpwood prices; Newman and Wear (1993) found just the opposite; and Royer and Vasievich (1987) found neither price to be significant.

The models employed in these papers differ in many ways, but it appears that the significance of sawtimber prices often disappears when income is added as an explanatory variable. Only two of six studies find positive effects of sawtimber price on reforestation when including owner income. On the other hand, two of three studies including both pulpwood prices and income find price to be significant. It is possible that income and price are correlated in some studies (e.g., the income variable used may include timber income, which depends on timber price). However, income is typically measured as either regional income per capita, regional net farm income per capita, or the midpoint of an income range reported on landowner surveys. This makes it unlikely that the income measure used in the model will be strongly correlated with timber prices unless a large proportion of regional income is received from timber sales. Alternatively, this finding suggests that capital constraints (alleviated by higher income) may be more important than sawtimber price in influencing NIPF landowner reforestation behavior. In other words, after a measure of available resources for forestry investment (e.g., income) is included, sawtimber price may have little additional explanatory power.[12] This is consistent with the finding of large positive effects of government cost sharing (described below under Policy Variables), which reduces capital requirements. However, it is difficult to explain why this would not be the case for pulpwood prices as well and why income is significant in only 56 percent of the studies that include it if it is an important measure of capital constraints. It may be the case that income is correlated with knowledge and use of cost sharing.

Most researchers also included planting costs in their models of reforestation. It is expected that an increase in the costs of reforestation will lead NIPF owners to conduct less reforestation, choosing instead to allow their forests to regenerate without active management or converting to a different land use. The empirical results are generally supportive, showing significant negative impacts of the cost of planting in 67% of studies that included this variable, while the other

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[11] This percentage is based the number of studies that have at least one price (either sawtimber or pulpwood) that is statistically significant out of all studies that include price, i.e., 8 of 13 studies.

[12] It is also quite possible that variables used to represent price expectations (often current prices) do not adequately reflect actual landowner expectations of prices at harvest, thereby reducing the estimated explanatory power of timber prices.

papers did not find significant impacts. Depending on the study, increasing reforestation costs were either found to reduce the acreage planted or the probability of planting.

Both short term and long term interest rates may also have an impact on the reforestation decision for NIPF landowners. Short term interest rates represent the opportunity cost of investing in forestry and are expected to be negatively related to forestry investment. As the return to alternative investments rises, investment in reforestation becomes less attractive, other things being equal. Only four studies included short term interest rates in their econometric models, but all four found significant negative effects on reforestation. These results suggest that the returns to alternative investments may be an important omitted variable in the majority of reforestation studies. Another potential substitute for investments in forestry is to convert the land to agriculture. Cohen (1983) and Kula and McKillop (1988) include agricultural prices indices to represent alternative investments in agriculture and find significant negative effects of agricultural prices on reforestation. As expected, the results imply that increases in the returns to agriculture tend to reduce the level of investment in reforestation.

Miranda (1989) argues that forestry investments have performed better than agricultural investments during periods of actual or anticipated inflation and that standing timber can be used as an inflationary hedge, presumably because forest resources are real assets. If we combine this information with the view that interest rates contain an inflationary expectations component, we could see how forestry investment and long-term interest rates should be positively correlated if NIPF owners in fact perceive forestry investments as a hedge against inflation (Miranda, 1989). However, the results for long term interest rates are not as consistent as those for short term interest rates. Of the four studies including this variable, one finds a significant positive impact, one finds a significant negative impact, and the other two do not find a significant influence of long term interest rates.

4.1.2 Policy Variables

In contrast to the economic drivers discussed above, the effects of the policy variables on reforestation are almost universally highly significant no matter how they are specified. Cost sharing is most often included in the models as a dummy variable indicating NIPF landowner participation in or knowledge of such programs, although some studies include dollar figures of spending on cost sharing programs. Among studies that included a variable for government cost sharing to determine whether it has an effect on overall reforestation, every one estimated a statistically significant positive effect.[13] For technical assistance, all but one of the studies that included this variable found a significant positive effect on reforestation. Even the study that did not (Hyberg and Holthausen, 1989) was close to the cutoff for significance used in this review.

[13] de Steigeur (1984) included a variable for cost sharing and did not find a significant effect, but it was in the context of examining the impact of cost sharing programs on non-cost shared private tree planting rather than testing the effect of cost sharing on total reforestation. Thus, the results for cost sharing from this study suggest no significant crowding out of private investment rather than no effect on reforestation.

They did not find significance at the 10 percent level, but technical assistance was significant at the 15 percent level in their model.

4.1.3 Owner Characteristics

Among the owner characteristics most commonly included in the reforestation models, only income showed any evidence of influencing reforestation. Neither owner age nor owner occupation were found to be significant in any of the studies in which they were present, whereas income was positive and significant in 56% of studies where it was included. Income would generally be expected to have a positive influence on reforestation because it implies better access to capital necessary for reforestation. However, it is possible that income is correlated with knowledge and use of cost sharing, which may be reducing the proportion of studies in the literature that find it to be significant.

4.1.4 Plot/Resource Conditions

Finally, plot/resource variables were included in 31% of the models. The variable used most commonly (5 studies) was plot size, which was found to be positive and significant in 60% of the papers in which it was included. Factors such as plot quality and tree species may also have some impact on the reforestation decision, but few researchers explored this possibility. Two of the three studies that included site quality found a statistically significant positive effect of site quality on reforestation. Zhang and Pearse (1997) also looked at the effects of tree species on reforestation and found that planting was significantly more likely relative to the “other species” category (which include pine, cypress, and hardwood, among others) for Douglas fir and spruce trees, and significantly less likely for balsam and hemlock trees. They argue that this likely reflects the tendency to actively plant Douglas fir and spruce naturally regenerate balsam and hemlock, presumably a finding limited to their study area.

4.2 A Vote Count of Silvicultural Treatments

In the same format as used for reforestation, Table 7 presents the findings of empirical research studies examining silvicultural treatments. The factors included in these models are the same as those used for reforestation at the broad aggregate level, including: market drivers, policy variables, owner characteristics, and plot/resource conditions. However, there are a wider array of variables that seem to affect the silvicultural treatment decision and much less reliance on market drivers to explain NIPF silvicultural investment than reforestation. Both owner characteristics and plot/resource conditions are included in 100% of studies, while market drivers and policy variables are included in 60%. The variable most likely to be included is plot size, which was included in 100% of studies.

There are numerous variables that were statistically significant in 100% of studies where they were included. Interest rate, cost sharing, technical assistance, tax incentives, income, owner location, tree species, and road density were all significant in each study where they appeared.

However, no variable is significant in more than three of the five studies while all variables are significant in at least one study. Before turning to a discussion of the results below, it is critical to point out that these findings are somewhat limited by the small size of the sample (n = 5) of empirical studies on silvicultural treatments.

4.2.1 Market Drivers

We can expect that increases in the price of timber will tend to cause more silvicultural activity, other things being equal, because the return to timber production (and hence activities that increase timber productivity) is higher. However, timber prices are only included in three of the five models and are significant in only one of those models. Interest rates were included in one study and were found to have a significant positive effect, which seems to be counterintuitive. An increase in interest rates indicates that the return to alternative investments is rising, making investments in silvicultural treatments relatively less attractive. Zhang and Pearse (1996) note that the interest rate is expected to have a negative effect, but do not offer an explanation for their finding of just the opposite result.

4.2.2 Policy Variables

Each of the policy variables included in these studies (cost sharing, technical assistance, and tax incentives) are significant in every study that includes them. By and large, these variables have the expected positive effects. That is, in 71% of the cases cost sharing, technical assistance and/or tax incentives encourages silvicultural treatment. The two exceptions [Löyland et al. (1995) and Zhang and Flick (2001)] did find positive effects of cost sharing on reforestation, implying that cost sharing programs are encouraging replanting, but not followup management activities. However, this is presumably an artifact of the dependent variable, at least in Zhang and Flick's analysis.[14]

4.2.3 Owner Characteristics

Owner characteristics are quite important for determining the likelihood of conducting silvicultural treatments and/or the extent to which these activities will be conducted. NIPF owner income and owner education/training are significant and positive in 75% of the studies that included them, while the proximity of the landowner to the site has significant positive effects in 67% of studies that included those variables. Age appears to be negatively related to investment in silvicultural activities, with 67% of the studies that included age finding significant effects.

[14]Because the dependent variable is measuring private silvicultural treatments, government cost sharing will tend to have a negative effect if there is substitution of public for private capital, which is what Zhang and Flick find. For Löyland et al., it is less clear why the effect of cost sharing is negative because the dependent variable is the probability of engaging in young growth tending, which seemingly should be positively correlated with cost sharing.

4.2.4 Plot/resource Conditions

Finally, the plot/resource conditions that were typically included are plot size and a site index. Improvements in site quality increase the amount of silvicultural activity taking place in each of the three studies where it is included, while plot size was found to have a positive influence on silvicultural investment in only 40% of the studies that included it as a variable in estimation. Road density was found to have a positive effect on investment in the one study where it was included, presumably because it increases ease of access to the forest site. Zhang and Pearse (1996) include dummy variables for location and tree species, which are found to have significant effects that may be either positive or negative depending on the particular location or species type.

5.0 A META-SUMMARY OF NIPF MANAGEMENT

Our review identifies four primary factors that influence both the reforestation and silvicultural treatments, including: market drivers, policy variables, owner characteristics, and plot/resource conditions. Across the 19 studies reviewed, we found the following general patterns. Studies of reforestation are most likely to include market drivers as explanatory variables, followed by policy variables, owner characteristics, and plot/resource conditions. Among individual variables, timber prices (primarily sawtimber prices) and forestry policies (primarily cost-share) are used in the majority of studies. However, there is little consensus on the importance of other variables that may influence reforestation. Planting costs and landowner income are the only other variables that are used in more than half of the reforestation papers reviewed. As noted earlier, by simply including a specific variable in an econometric model, researchers do not guarantee statistically significance or influence on forest management for that variable. Based on our statistical significance criteria, NIPF reforestation is primarily driven by timber prices, planting costs, government cost sharing and technical assistance, returns to alternative investments (e.g., short term interest rates, agricultural crop prices), owner income, and site quality.

In a much smaller set of studies, silvicultural treatments are typically modeled using the same four primary categories of variables as those used in reforestation models. However, there is much more emphasis on the owner characteristics and plot/resource conditions and far more uncertainty concerning the variables to be included in these models than for reforestation models. The most commonly used explanatory variables are plot size, age, income, and forestry training. Only two of five papers include market factors such as timber and land prices in their models. Turning to statistical significance, the most consistent influences include cost-share, technical assistance, owner training and income, and site index.

There are several important issues with some of the data that has been used in prior research on NIPF management. Some common problems include inadequate data on the exact year of the management activity; reliance on broad regional average data instead of plot level data; difficulty in matching economic data with management activity in a temporally and spatially consistent manner; using data on awareness of government cost sharing programs, rather than actual participation in these programs; and inadequate characterization of landowner preference heterogeneity. While any or all of these problems could bias the results of individual studies, our use of vote counting technique attempts to identify the variables for which the results are consistent despite variation in the data used across studies. That is, unless a particular variable suffers from substantial problems and consistent biases in all studies, vote-counting allows us to pick up the most general results. We must remember, however, that our focus on statistical significance alone does not allow us to tell the whole story because it says nothing about the magnitude of the effect, typically measured as a marginal effect. Unfortunately, the studies generally either do not report or do not provide enough detail to calculate the marginal probability of management.

Additionally, although meta-analysis can be a useful way to quantitatively synthesize research findings, there are a few general caveats to this approach. First, meta-analysis can reduce subjectivity by bringing together a number of studies, but subjectivity is not eliminated because the analyst is instrumental in the selection of studies. Studies are typically selected using arbitrary criteria such as statistical cut-off point and data compatibility. Second, meta-analysis assumes the separability of studies. However, studies draw on each other – particularly those selected for a meta-analysis by virtue of their presence in the relevant published literature – and therefore may perpetuate errors. Third, a number of professional studies are not available for analyses because of confidentiality and lack of interest in publication. Finally, the inherent nature of economic research constrains the use of many techniques commonly employed in natural sciences and leads to non-standardized output. Unlike strict experimental settings, the reporting of assumptions, error distributions, and data idiosyncrasies are not standardized. These limitations should be considered in designing future meta-analyses of NIPF management.

Consider some lessons for the research community investigating NIPF management. In the best scenario, researchers would be required to consider at a minimum the full range of factors discussed in this paper and describe how these factors affect the statistical models of reforestation and silviculture. While this would clearly limit the ability to work with convenient but incomplete data sets, the resulting analysis would be based on a model that is conceptually sound and empirically complete. In general, it would force researchers to expend more effort in research design. These ideas also suggest that field journals should consider standardizing the reporting requirements for results published in their journal. At the very least, editors could require authors to report a basic number of descriptive statistics and marginal probabilities, which would facilitate more sophisticated meta-analyses of NIPF management.

One of the most important policy implications of our meta-analysis is that empirical analyses more frequently find that NIPF owners respond to targeted government programs (assistance and cost share) than to other factors, including market price.[15] An important question, then, is the extent to which cost sharing programs are leading to new investments in reforestation as opposed to replacing private investment. Although the extent of substitution of public for private investment is unclear, all evidence suggests that targeted government programs are leading to a large increase in the amount of NIPF reforestation and silvicultural investment.[16] Such findings may influence the design of policies to encourage production of both traditional forest outputs, such as timber, and non-traditional outputs such as sequestered carbon, wildlife habitat, water quality and quantity, and other environmental services. As Kluender et al. (1999) point out in criticizing government programs designed to induce future timber production, while reforestation has increased, there has been a much smaller corresponding increase in timber harvest. This is to be expected if government programs increase NIPF wealth sufficiently that NIPF owners substitute forest amenities for increased forest income because they are maximizing utility rather than just profit (Hyberg and Holthausen, 1989; Pattanayak et al., 2002 and forthcoming).

To summarize, we take the first step in reviewing the growing literature on NIPF management by conducting a simple meta-analysis of 19 empirical forest management studies. We identify four primary factors that could influence both the reforestation and silvicultural investments, including: market drivers, forest policies, owner characteristics, and plot/resource conditions. We find that markets and policies are the most commonly studied, a modeling choice that is somewhat justified by the finding that these are important statistical influences on reforestation choices. However, we find too few empirical studies on silvicultural investments to offer generalizable findings. It is our hope that in the future researchers will take on the challenge of studying the full set of factors influencing silvicultural investments in particular and forest management in general.

[15] One possible explanation for this is that owner price expectations are not being correctly modeled. Current prices are often used as a proxy for expected future prices, although landowners may have more complex methods of forming their price expectations.

[16] Several studies have examined this question, but the results have been inconsistent. de Steiguer (1984), Lee et al. (1992), Royer (1987), and Brooks (1985) found that there was not significant substitution taking place, while Cohen (1983), Boyd (1984), Kluender et al. (1999), and Zhang and Flick (2001) all find some evidence of substitution taking place. In fact, Cohen concluded that between 30 and 50 percent of the acres planted using cost-sharing would have been planted without the subsidies. In addition, Bliss and Martin (1990) report landowners' statements that they are substituting public funds for their own funds.

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Table 1. Total Tree Planting by Ownership Category in FY 1998

	Acres	Percentage of All Planting
Federal Government		
National forests	146,887	5.6%
Department of the Interior	27,996	1.1%
Other federal agencies	13,686	0.5%
Subtotal	188,569	7.2%
State and Local Government		
State forests	51,880	2.0%
Other state lands	11,541	0.4%
Local government	19,401	0.7%
Subtotal	82,822	3.2%
Private		
Forest industry	1,095,317	41.7%
Nonindustrial private	1,257,973	47.9%
Subtotal	2,353,290	89.7%
Total	2,624,681	100.0%

Source: Moulton and Hernandez, 2000.

Table 2. Tree Planting by Ownership Category and Region in FY 1998

	Federal Government	State and Local Government	Nonindustrial Private Forest	Forest Industry	Total
South					
Acres	31,232	37,463	1,108,598	888,183	2,065,476
Percentage of regional acreage	1.5%	1.8%	53.7%	43.0%	100.0%
West					
Acres	148,021	27,650	81,486	189,588	446,745
Percentage of regional acreage	33.1%	6.2%	18.2%	42.4%	100.0%
North					
Acres	9,316	17,643	67,424	17,546	111,929
Percentage of regional acreage	8.3%	15.8%	60.2%	15.7%	100.0%

Source: Authors' calculations based on data from Moulton and Hernandez, 2000.

Table 3. Silvicultural Treatments by Ownership Category in FY 1998

	Acres	Percentage of all Planting
Federal Government		
National forests	300,202	12.5%
Other federal agencies	86,958	3.6%
Subtotal	387,160	16.1%
State and Local Government		
All state and local government	96,114	4.0%
Subtotal	96,114	4.0%
Private		
Forest industry	1,632,710	68.1%
Nonindustrial private	282,559	11.8%
Subtotal	1,915,269	79.9%
Total	2,398,543	100.0%

Source: Moulton and Hernandez, 2000.

Table 4. Silvicultural Treatments by Ownership Category and Region in FY 1998

	Federal Government	State and Local Government	Nonindustrial Private Forest	Forest Industry	Total
South					
Acres	43,171	22,441	151,195	117,864	334,671
Percentage of regional acreage	12.9%	6.7%	45.2%	35.2%	100.0%
West					
Acres	328,559	69,490	48,973	1,453,296	1,900,318
Percentage of regional acreage	17.3%	3.7%	2.6%	76.5%	100.0%
North					
Acres	15,430	4,156	79,333	61,550	160,469
Percentage of regional acreage	9.6%	2.6%	49.4%	38.4%	100.0%

Source: Authors' calculations based on data from Moulton and Hernandez, 2000.

Table 5. Summary of Econometric Studies of NIPF Management

Study	LHS and Technique
REFORESTATION	
Alig (1986) Southern U.S.; pooled cross-section time series	Share of land allocated to each of three nonforest land uses (crops, pasture/range, urban) and three forest ownerships (farmer, forest industry, and other private) 6-equation system estimated using SUR
Brooks (1985) 2 southern regions (Southeast and Southcentral); rich panel	Total acres planted OLS w/distributed lag on cost-share payments
Cohen (1983) Southern U.S.; rich panel	Total acres planted on nonindustrial forestland OLS
	Acres planted without cost-sharing funding on private nonindustrial forestland OLS
de Steiguer (1984) 10 U.S southern states.; rich panel	Total out-of-packet autonomous expenditure by NIPF investors for tree planting OLS with geometric lag for prices and interest rates
Hyberg and Holthausen (1989) Georgia; cross-section (survey)	0 = No replanting 1 = Replanting Logit
Kula and McKillop (1988) Northern Ireland; rich panel	Acres under softwood afforestation OLS with distributed lags
Lee et al. (1992) Southern U.S.; panel	Non-cost-shared NIPF pine plantation acreage OLS
	Non-cost-shared industrial pine plantation acreage OLS
Lee and Murray (1990) Georgia, FIA, cross-section	Nonindustrial planted acreage OLS
	Industrial planted acreage OLS
Löyland et al. (1995) Norway, cross-section	0 = No planting and seeding 1 = Planting and seeding activities Probit
	Share of forest area that is planted OLS

(continued)

Table 5. Summary of Econometric Studies of NIPF Management (Continued)

Study	LHS and Technique
REFORESTATION	
Miranda (1989) 13 states in the Southern U.S. for 1953-85, panel	Nonindustrial forestry investment (acres regenerated) OLS
	Industrial forestry investment (acres regenerated) OLS
Newman and Wear (1993) 5 U.S. southeastern states; thin panel	Restricted profit function
	Sawtimber output supply
	Pulpwood output supply
	Regeneration derived demand
	(each estimated for both NIPF and industrial owners)
	8-equation system estimated using SUR
Royer (1987) 12 U.S. southern states, cross-section (survey)	0 = No replanting 1 = Replanting Logit
Royer and Moulton (1987) 9 U.S. southern states, cross-section (survey)	0 = No reforestation 1 = Reforestation Logit
Royer and Vasievich (1987)	0 = No reforestation 1 = Reforestation Logit
Zhang and Flick (2001) SC and NC, cross-section (survey)	0 = No replanting 1 = Replanting Probit
Zhang and Pearse (1997) British Columbia, Canada; rich panel	0 = No Planting 1 = Planting Logit

(continued)

Table 5. Summary of Econometric Studies of NIPF Management (Continued)

Study	LHS and Technique
SILVICULTURAL TREATMENTS	
Boyd (1984) North Carolina; survey of commercial forest landowners	0 = No Timber Stand Improvement 1 = Timber Stand Improvement Probit
Löyland et al. (1995) Norway, cross-section	0 = No young growth tending activities 1 = Young growth tending activities Probit
	Share of forest area with young growth tending activities OLS
Romm et al. (1987) Northern California; thin panel	0 = No NIPF forestry investment 1 = NIPF Forestry investment Logit
	0 = No invest. in forest improvements 1 = Investment in forest improvements Logit
Zhang and Flick (2001) SC and NC, cross-section (survey)	Private forestry investment expenditures OLS
Zhang and Pearse (1996) British Columbia, Canada; rich panel	Silvicultural investment per hectare OLS

NA = Not available.

Table 6. Variables Affecting NIPF Reforestation Behavior

	Market Drivers						Policy Variables		Owner Characteristics			Plot/ Resource Conditions	
Study	**Saw Prices**	**Pulp Prices**	**Planting Costs**	**Real Ag Crop Price Index**	**Interest-SR**	**Interest-LR**	**Cost Share**	**Assist**	**Income**	**Age**	**Occupation**	**Plot Size**	**Site Quality**
Alig (1986)	0					0	+		+				
Brooks (1985)	0		–				+						
Cohen (1983)	+		0	–		–	+		0				
de Steiguer (1984)	0				–		0[a]		+				
Hyberg and Holthausen (1989)	+		–				+	0	0				
Kula and McKillop (1988)	+			–			+						
Lee et al. (1992)	+		–		–		+						
Lee and Murray (1990)	+		0									+	
Loyland et al. (1995)							+	+		0		+	+
Miranda (1989)					–	+	+		0				
Newman and Wear (1993)	+	0	–										
Royer (1987)	0	+	–				+	+	+		0	0	

(continued)

Table 6. Variables Affecting NIPF Reforestation Behavior (Continued)

	Market Drivers						Policy Variables		Owner Characteristics			Plot/ Resource Conditions	
Study	**Saw Prices**	**Pulp Prices**	**Planting Costs**	**Real Ag Crop Price Index**	**Interest-SR**	**Interest-LR**	**Cost Share**	**Assist**	**Income**	**Age**	**Occupation**	**Plot Size**	**Site Quality**
Royer and Moulton (1987)		+	0				+	+	+		0		
Royer and Vasievich (1987)	0	0					+		+		0		
Zhang and Flick (2001)	0		–		–	0	+	+	0	0		0	0
Zhang and Pearse (1997)												+	+
Included	12	4	9	2	4	4	13	5	9	2	3	5	3
Significant	6	2	6	2	4	2	12	4	5	0	0	3	2
Pos.	6	2	0	0	0	1	12	4	5	0	0	3	2
Neg.	0	0	6	2	4	1	0	0	0	0	0	0	0
Not Significant	6	2	3	0	0	2	0	1	4	2	3	2	1

(continued)

Table 6. Variables Affecting NIPF Reforestation Behavior (Continued)

	Market Drivers						Policy Variables		Owner Characteristics			Plot/ Resource Conditions	
Study	**Saw Prices**	**Pulp Prices**	**Planting Costs**	**Real Ag Crop Price Index**	**Interest-SR**	**Interest-LR**	**Cost Share**	**Assist**	**Income**	**Age**	**Occupation**	**Plot Size**	**Site Quality**
Percent Included	75%	25%	56%	13%	25%	25%	81%	31%	56%	13%	19%	31%	19%
Percent Significant (Included Studies)	50%	50%	67%	100%	100%	50%	92%	80%	56%	0%	0%	60%	67%
Percent Significant (All Studies)	38%	13%	38%	13%	25%	13%	75%	25%	31%	0%	0%	19%	13%

[a]Cost sharing is included in the model for this paper, but in the context of its effect on non-cost shared private tree planting only. Thus, the coefficient from this study implies there is not significant crowding out of private investment due to cost sharing. It does not imply that cost sharing is not having an effect on reforestation overall.

Table 7. Variables Affecting NIPF Silvicultural Treatment Behavior

	Economic Drivers		Policy Variables			Owner Characteristics				Plot/Resource Conditions				
Study	**Saw Prices**	**Interest Rate**	**Cost Share**	**Assist**	**Tax Incentive**	**Income**	**Age**	**Educ Training**	**Proximity to Forest**	**Location**	**Plot Size**	**Site index**	**Species**	**Road Density**
Boyd (1984)	+		+	+		0		+	+		+			
Loyland et al. (1995)			–	+		+	0	+	+		+	+		+
Romm et al. (1987)						+	–	0	0		0			
Zhang and Flick (2001)	0		–[a]	+	+	+	–	+			0	+		
Zhang and Pearse (1996)	0	+								+, –	0	+	+, –	
Included	3	1	3	3	1	4	3	4	3	1	5	3	1	1
Significant	1	1	3	3	1	3	2	3	2	1	2	3	1	1
Pos.	1	1	1	3	1	3	0	3	2	na	2	3	na	1
Neg.	0	0	1	0	0	0	2	0	0	na	0	0	na	0
Not Significant	2	0	0	0	0	1	1	1	1	0	3	0	0	0
Percent Included	60%	20%	60%	60%	20%	80%	60%	80%	60%	20%	100%	60%	20%	20%
Percent Significant (Included Studies)	33%	100%	100%	100%	100%	75%	67%	75%	67%	100%	40%	100%	100%	100%
Percent Significant (All Studies)	20%	20%	60%	60%	20%	60%	40%	60%	40%	20%	40%	60%	20%	20%

[a]Although this study finds a negative relationship between cost sharing and silvicultural activities, the model is structured such that this implies some crowding out of private silvicultural investment. It does not imply that cost sharing reduces the level of silvicultural investment overall.