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Econometric 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 non-industrial private forest (NIPF) management or whether the existing results are case-specific. In this paper, we systematically review the empirical economics literature on NIPF timber harvesting, reforestation, and timber stand improvements (TSI). We confirm four primary categories of management determinants: 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 harvesting, reforestation and TSI within these four categories. Despite substantial differences in the variables used across models, the use of meta-analysis enables the systematic identification of the factors that are most important in explaining NIPF management. We conclude with some methodological and policy suggestions.

JEL classification: Q23; C8

Keywords: Timber harvesting; Reforestation; Silvicultural treatments; Microeconomics; Meta-analysis; Vote-counting

1. Introduction

1.1. Microeconometric models of forest management

Forest landscapes in the US are shaped 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]

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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, 2002).

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Microeconometric models are key elements of such modeling systems because they explain landowner behavior and management based on market, owner, policy and resource characteristics and they can project forest outputs, inventories and land use. Non-industrial private forest (NIPF) management practices such as timber harvesting, reforestation and timber stand improvement (TSI) are of particular interest. While a large share of US timber has historically been produced on NIPF lands, the combination of increasing demand for wood products and recent reductions in timber harvesting on publicly owned 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 population along with changes in other demographic variables are leading to both increasing demand for and increasing scarcity of amenity services associated with standing forests, especially in urban areas (Mansfield et al., 2002; Cassingham et al., 2002). However, it is unclear whether the existing econometric models offer general conclusions concerning NIPF management or whether the existing results are case-specific.

In this paper, we systematically review the empirical economics literature on NIPF management and identify the determinants of forest management. 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 timber harvesting, reforestation and TSI. Given that NIPF landowners control a large share of timberland in the US, especially in the south, this type of information can help assess future forest landscapes and develop sound forest policy. [2]

2. The role of literature reviews

There is a 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 demonstrate empirical consistencies or 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.

The simplest of the meta-analytical methods is vote-counting, 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 not significant. 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 studies within a given research area.

The only previous literature review of NIPF management we identified was Alig et al. (1990). Their paper reviewed the literature on NIPF timber manage-

[2] Approximately 69% of timberland is controlled by NIPF landowners in the south compared with 58% in the US overall (USDA Forest Service, 2002; Smith et al., 2001). The states included in the South region are Alabama, Arkansas, Florida, Georgia, Kentucky, Louisiana, Mississippi, North Carolina, Oklahoma, South Carolina, Tennessee, Texas and Virginia.

ment behavior in the US and drew some general conclusions based on findings that were consistent across studies. However, they did not provide a systematic quantitative summary of their findings. The primary improvements offered by our study are the use of a meta-analysis framework to organize and quantitatively present our results, the inclusion of additional papers that have become available in the last 12 years and an expanded comparison and discussion of the studies being included.

To conduct our literature review, we collected all of the studies included in the Alig et al. (1990) review and searched the databases Agricola, Biological abstracts and Scientific citation for additional publications from the last 20 years that included econometric estimates of the influence of factors affecting timber harvesting, reforestation and/or TSI[3] decisions. 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.[4] 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 18 econometric studies of timber harvesting, 16 econometric studies of reforestation and five studies that estimate econometric models of TSI.[5] Table 1 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 identified were conducted in the US, predominantly in the South, but there are also studies conducted using data from Ireland, Canada, Finland and Norway. Most of this literature relies 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).[6] Many of the models estimated are binary choice models (e.g. probit, logit) of the harvesting, reforestation or TSI decision. These models estimate the influence of each independent variable on the probability that the activity being modeled will take place. In addition, there are several studies that rely on ordinary least squares (OLS) 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 harvesting, reforestation and TSI. 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 cannot estimate meta-models of ‘effects size’ because of the discrete choice nature of our dependent variable in most studies (e.g. either reforest or not) and the lack of details in the studies on continuous measures of response, such as the 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.[7] That is, for all studies included in the meta-analysis, we determine for each variable of interest whether the

[3] For the purposes of our review, TSI is defined as thinning, fertilizer use, insecticide use, weed control and other treatments designed to increase forest productivity.

[4] 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.

[5] Several papers estimate models for more than one of the three NIPF management categories used in this review. There are a total of 32 different papers included in the review.

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

[7] There were some variables to which the vote-counting method was not applied, typically because they were unique to a single study (e.g., rural population, intent to bequeath all timber, proximity to endangered species habitat, etc.).

Table 1
Summary of econometric studies of NIPF management

Study	LHS and technique
Timber harvesting	
Binkley (1981) New Hampshire; panel	0 = No harvest 1 = Harvest Logit
Bolkesjo and Baardsen (2002) Norway; panel	Harvest intensity Simultaneous equations Tobit
Boyd (1984) North Carolina; cross-section (survey of commercial forest landowners)	0 = No harvest 1 = Harvest Probit
Conway et al. (2000) Virginia; cross-section	0 = No harvest 1 = Harvest Probit
Dennis (1989) New Hampshire; panel	0 = No harvest >0 = Harvest volume Tobit
Dennis (1990) New Hampshire; panel	0 = No harvest 1 = Harvest Probit
Holmes (1986) Connecticut; cross-section	0 = No harvest 1 = Harvest Logit
Hyberg and Holthausen (1989) Georgia; cross-section	0 = No harvest 1 = Harvest Logit
Kuuluvainen and Salo (1991) Finland; cross-section	Harvest volume Tobit
Kuuluvainen et al. (1996) Finland; cross-section	Harvest volume Tobit; 3 separate
Kuuluvainen and Tahvonen (1999) Finland; panel	Harvest volume Tobit
Lee (1998) North Carolina; cross-section (FIA data)	0 = No harvest 1 = Harvest Probit
Lee and Murray (1990) Georgia; cross-section (FIA data)	Non-industrial harvested acreage OLS
Löyland et al. (1995) Norway; cross-section	0 = No harvest 1 = Harvest Probit Volume of harvest Ordinary least squares (OLS)
Newman and Wear (1993) Five Southern US states; cross-section	Restricted profit function Sawtimber output supply Pulpwood output supply Regeneration derived demand

Table 1 (*continued*)

Study	LHS and technique
	(each estimated for both NIPF and industrial owners) 8-equation system estimated using seemingly unrelated regression (SURE) techniques
Pattanayak et al. (2003) North Carolina; cross-section (FIA data)	0 = No harvest 1 = Harvest Probit
Pattanayak et al. (2002) 12 Southeastern US states; cross-section (FIA data)	Harvest volume 3SLS
Prestemon and Wear (2000) North Carolina; panel (FIA data)	0 = No harvest 1 = Harvest Probit
Reforestation	
Alig (1986) Five Southeastern US states; panel	Share of land allocated to each of three non-forest land uses (crops, pasture/range, urban) and three forest ownerships (farmer, forest industry and other private) 6-equation system estimated using SURE
Brooks (1985) Two Southern US regions (Southeast and Southcentral); panel	Total acres planted by non-industrial private owners OLS w/distributed lag on cost-share payments
Cohen (1983) Southern US; panel	Total acres planted on non-industrial forestland OLS Acres planted without cost-sharing funding on private non-industrial forestland OLS
de Steiguer (1984) 10 Southern US states; panel	Total out-of-pocket autonomous expenditure by NIPF investors for tree planting OLS with geometric lag for prices and interest rates
Hyberg and Holthausen (1989) Georgia; cross-section	0 = No replanting 1 = Replanting Logit
Kline et al. (2002) 12 Southern US states; panel	Acres planted in trees by non-industrial landowners OLS
Kula and McKillop (1988) Northern Ireland; panel	Acres under private softwood afforestation OLS with distributed lags
Lee et al. (1992) 13 Southern US states; panel	Non-cost-shared NIPF pine plantation acreage OLS
Lee and Murray (1990) Georgia; cross-section (FIA data)	Non-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
Miranda (1989) 13 Southern US states; panel	Non-industrial forestry investment (acres regenerated) OLS

(continued on next page)

Table 1 (*continued*)

Study	LHS and technique
Newman and Wear (1993) Five Southern US states; cross-section	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 SURE
Royer (1987) 12 Southern US states; cross-section (survey)	0 = No replanting 1 = Replanting Logit
Royer and Moulton (1987) Nine Southern US states; cross-section (survey)	0 = No reforestation 1 = Reforestation Logit
Royer and Vasievich (1987)[a] 12 Southern US states; cross-section (survey) Nine Southern US states; cross-section (survey)	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; panel	0 = No Planting 1 = Planting Logit
Silvicultural Treatments	
Boyd (1984) North Carolina; cross-section (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; cross-section	0 = No NIPF forestry investment 1 = NIPF forestry investment Logit 0 = No investment 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; panel	Silvicultural investment per hectare OLS

[a] This study uses two different data sets. One is the same as Royer (1987); the other is the same as Royer and Moulton (1987). Since the models and results are almost identical, we do not include it separately in the vote counting because that would be double counting.

variable was included in the study and if so, whether there was a statistically significant positive or negative relationship with the forest management decision.[8] These results are then summarized by calculating:

a. The percentage of studies that included each variable.
b. 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.
c. The percentage of studies that found a statistically significant effect out of all studies.

For studies that provide results based on multiple datasets, we included the results for each dataset as a separate 'vote' as long as the sample size was 50 or greater for each subset of the data. Results for different regions using the same model give us new information for our meta-analysis, essentially a vote from each set of data. However, where numerous regression results (often specifications differ only slightly from one another) are reported for the same data set, the results are included in the vote-counting analysis only once (from what we determine is the most appropriate model) to avoid overweighting the results from a single dataset.

3. Analytical framework for NIPF landowner behavior

We drew on the theoretical literature and the empirical studies in our meta-analysis to develop a simple organizing structure of the factors influencing forest management choices. Similar to other production activities, forestry involves the selection of the optimal set of inputs to produce the desired outputs by forest owner–managers. Forest product outputs such as timber and amenities can in turn be conceived as inputs in the production of owner wellbeing. It is beyond the scope of this paper to develop a formal model of forest management (see Binkley (1981), Max and Lehman (1988) and Pattanayak et al. (2003) for a more rigorous treatment of this issue). Instead, we present a simple analytical framework that draws on consumption and production theory to characterize three management choices of forest owners—harvesting (HRV), reforestation (REF) and TSI—and to identify four general classes of determinants of these choices.

Forest owner–managers produce a variety of forest products using several categories of inputs, including forestland, timber growing stock and labor, materials and machinery to engage in various management activities, including HRV, REF and TSI. Forestland refers to the land being used to produce forestry outputs, which can be varied by conversion between uses, e.g. from forestry to agriculture or vice versa. Growing stock is an aggregate measure of accumulated forestry capital adjusted by forest regeneration, growth and removals. HRV is often measured in terms of volume of timber harvested, categorized into different species of wood. REF effort includes capital, labor and material inputs necessary to plant trees. TSI refers to actions such as the use of fertilizers, application of insecticides, pesticides or herbicides, thinning of competing vegetation and other management activities that increase the growth rate of the targeted species.

In analytical studies of the investment behavior of NIPF owners, two basic theories are used to explain their actions: profit- and utility-maximization. Profit-maximization essentially assumes that forest owners make decisions that will maximize the level of discounted profits over time without consideration of the benefits associated with non-market goods produced by their forests. Utility-maximization, however, recognizes that forest owners may gain non-pecuniary benefits such as aesthetics, recreation and wildlife habitat from the forest stands on their land in addition to the value of their timber. This is an important distinction because the design of efficient public policy instruments depends on the accurate characterization of the factors influencing landowners' forestry management decisions (Pattanayak et al., 2002). For instance, Hyberg and Holthausen (1989) find that utility maximizers will harvest less often and invest more heavily in reforestation than profit maximizers, other things being equal.

It is typically assumed that land owned by the forest industry is managed according to profit-maximization, as economic theory would suggest for

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

private firms. NIPF behavior has often been modeled within a similar framework. However, to the extent that private landowners value non-timber amenities, these models inadequately account for suppliers choosing the structure of their forests to self-produce those amenities. More recent models of NIPF landowner behavior have recognized that factors other than profits may affect their investment decisions (e.g. Pattanayak et al., 2002).

Due to the potential divergence between forest management practices that maximize private and social welfare, federal, state and local governments are frequently involved in subsidizing and otherwise encouraging investments in forestry. These programs generally fall into the categories of direct tax incentives, input subsidies (e.g. cost-sharing) or indirect incentives, including government research, forest protection, training, technical assistance, extension and market information (see Best and Wayburn (2001) for an excellent introduction to direct and indirect incentives). The effect of each of these programs is to reduce the cost of forest management.

There are a variety of theoretical models that have been developed to explain NIPF management, but they generally rely on similar factors expected to affect management decisions (Binkley, 1981; Hyberg and Holthausen, 1989; Pattanayak et al., 2003). Assuming that NIPF landowners derive utility from non-market timber amenities and all other goods (measured by the present value of income, derived from both timber and non-timber sources), their utility function can be expressed as:

$$U = U(Y, N) \tag{1}$$

where Y is the present value of all future income and N is non-market timber amenities. This utility function is assumed to be increasing in both Y and N. Total income is the sum of timber income (Y_{tim}) and non-timber (Y_x) income (assumed to be exogenously determined)

$$Y = Y_x + Y_{\text{tim}}, \tag{2}$$

Timber income and output of non-market timber amenities are both functions of several primary factors. That is, forest owner–managers choose levels of HRV, REF and TSI to produce optimal combinations of timber income and non-timber amenities that maximize utility. Several factors influence the HRV, REF and TSI choices and our review of the theoretical and empirical literature identifies at least four sets of factors. Although there are several alternative ways that the determinants of these choices could be grouped, the following is one convenient and useful categorization.

- *Market drivers* (MD) 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. Increases in timber price are likely to increase HRV. Similarly, 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* (PV) 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 HRV, REF and TSI. Government policies that lower the costs of forest management (e.g. tax incentives, cost sharing and technical assistance) will tend to increase those forestry activities.
- *Owner characteristics* (OC) attempt to measure the preferences and resources of the NIPF landowner. Typically, landowner-specific preferences are therefore proxied by soci-demographic factors such as age and education. NIPF landowners' income is often used as a measure of their available resources for investment in forestry (suggesting imperfect capital markets) or their preferences for amenities, which are assumed to be a normal or luxury goods. In addition, investment may depend on characteristics of the landowner that may constrain his ability to become an investor (Zhang and Flick, 2001). It is impossible to determine a priori the direction of the influence on the three forestry decisions of this broad category.
- *Plot/resource* (PR) *conditions* relate to influences on the physical forestry production process 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.

In summary, forest owner–managers produce a mix of timber and non-timber products and maximize their welfare by choosing an optimal mix of HRV, REF and TSI. These choices in turn depend on all the factors described above and, therefore, the reduced form determinants are presented in equations Eqs. (3)–(5).

$$\mathrm{HRV} = f(\mathrm{MD}, \mathrm{PV}, \mathrm{OC}, \mathrm{PR}), \tag{3}$$

$$\mathrm{REF} = f(\mathrm{MD}, \mathrm{PV}, \mathrm{OC}, \mathrm{PR}), \tag{4}$$

$$\mathrm{TSI} = f(\mathrm{MD}, \mathrm{PV}, \mathrm{OC}, \mathrm{PR}). \tag{5}$$

Although the specific variables within the four primary factor categories that are most important in explaining behavior may differ between models of HRV, REF and TSI and the same variable is expected to have opposite signs in different models in some cases, this common categorization across models simplifies comparison of results. The variables that are included in the empirical studies reviewed typically can be assigned to one of the four categories defined in an internally consistent manner.

4. Counting votes on NIPF management

For each study, we reviewed the text and tables to identify variables that fit into the four categories defined above: market drivers, policy variables, owner characteristics and plot/resource conditions. We then applied the vote-counting technique to key variables within each broad category. Before we turn to the meta-analysis results, consider two caveats. First, the four primary sets of factors are not mutually exclusive because of complementarity and/or correlation between categories. To some extent, these interrelationships arise because we are using 'economic lenses', 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 accurately proxies specific relationships and factors and the reader may interpret these proxies differently.

4.1. A vote count of timber harvesting

Table 2 summarizes the vote counting results for the econometric timber harvesting 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 'zero'. 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 are the category most often included in models of timber harvesting (95%), followed by plot/resource conditions (90%), owner characteristics (65%) and policy variables (25%). There are four individual variables that are included in at least half of the studies: timber price (95%), growing stock (55%), plot size (55%) and income (50%).

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 timber harvesting 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 2 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: plot/resource conditions (94%), owner characteristics (92%), policy variables (80%)

Table 2
Variables affecting NIPF timber harvesting behavior

Study	Market drivers					Policy variables			Owner characteristics					Plot/resource conditions					
	Timber price	Land value	Harvesting cost	Planting cost	Interest rate[a]	Cost share	Assist	Rate of taxation	Income	Education/ training	Age	Owner proximity	Farmer	Plot size	Growing stock	Site quality	Amenities/ recreation opportunity	Accessibility of roads	Biodiversity of trees
Binkley (1981)	+								–	0	0			+					
Bolkesjo and Baardsen (2002)	+		–		0			–	0		0				+				
Boyd (1984)	+					0	+		0	0		0	+	+					
Conway et al. (2000) – Central VA	0											–		+	0	0	0	0	
Conway et al. (2000) – Southwest VA	0										–	0		0	0	+	0	+	
Dennis (1989)	0								–	+					+				–
Dennis (1990)	0				0				–	+				0	+				–
Holmes (1986)	+						0		–					+			–		
Hyberg and Holthausen (1989)	–	–		+		+	+		–				+	+					
Kuuluvainen and Salo (1991)	+				+				–		–		–	+	+				
Kuuluvainen et al. (1996)	0								0		–				+	+	–		
Kuuluvainen and Tahvonen (1999)	+				–				–										
Lee (1998)	+																+		–
Lee and Murray (1990)	0			0										+	+	+		+	
Löyland et al. (1995)						–	+			+	–	+		+		+		+	
Newman and Wear (1993)	+	–		–															
Pattanayak et al. (2003)	+		–												+	0	–		
Pattanayak et al. (2002) – Softwood	+														+				
Pattanayak et al. (2002) – Hardwood	+														0				
Prestemon and Wear (2000)	0													+				0	
Included	19	2	2	3	4	3	4	1	10	5	6	4	3	11	11	6	6	5	3
Significant	12	2	2	2	2	2	3	1	7	3	4	2	3	9	8	4	4	3	3
Positive	11	0	0	1	1	1	3	0	0	3	0	1	2	9	8	1	4	3	0
Negative	1	2	2	1	1	1	0	1	7	0	4	1	1	0	0	3	0	0	3
Not significant	7	0	0	1	2	1	1	0	3	2	2	2	0	2	3	2	2	2	0
Percent included	95%	10%	10%	15%	20%	15%	20%	5%	50%	25%	30%	20%	15%	55%	55%	30%	30%	25%	15%
Percent significant (Included studies)	63%	100%	100%	67%	50%	67%	75%	100%	70%	60%	67%	50%	100%	82%	73%	67%	67%	60%	100%
Percent significant (All studies)	60%	10%	10%	10%	10%	10%	15%	5%	35%	15%	20%	10%	15%	45%	40%	20%	20%	15%	15%

[a] The interest rate is not separated into short-term and long-term rates for timber harvesting (as it is for reforestation and TSI) because only one of the four studies that included an interest rate specified the term of the interest rate being used.

and market drivers (63%). Of course, statistical significance is only part of the story; magnitude is also important. However, there is generally insufficient information available in these studies to calculate the marginal efforts of the independent variables.

Given the predisposition toward variable significance as implicit model validation, 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 2, 'Percent significant (All studies)', shows the percentage of the timber harvesting 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 excluded the variable from their analyses intentionally (stepwise regressions or other types of data-mining). We discuss the results in more detail for each category below.

4.1.1. Market drivers

The variable in this category that is most commonly included in models of NIPF timber harvesting is timber price, which appears in all but one study. It is expected that timber prices and harvesting will be positively correlated. However, the influence of price is positive and significant in only 58% of studies that include price, with one study finding a negative effect and the rest finding no significant effect. Each of the studies that include land price or harvesting cost finds significant negative effects, but those variables are each included only in two studies, making it difficult to reach any conclusions. The results for interest rate are also inconclusive. Among the four studies that included a measure of interest rates (only one of the four studies specifies the term on which the rate is based and that was a rate for a 3-year treasury bill), one found the influence to be positive, one negative and two were not significant. Probably the most surprising result for the market drivers category is that less than two thirds of the harvesting studies find any of the variables in this category to be significant in their models, implying that NIPF landowners are less responsive to market signals than many researchers might expect or that there are substantial errors in the measurement of timber price variables.

4.1.2. Policy variables

There are relatively few harvesting studies that include this category of factors. Those that do examine policy variables find mixed results. Among the three studies that include cost sharing, one finds a positive effect, one a negative effect and the third finds no significant influence of cost sharing. The results are a little more consistent for technical assistance, where three of four studies find a significant positive effect. There is only a single study that includes a variable for tax rate on forestry production, but that study does find the expected negative sign. Given the small number of studies that include these variables, it is difficult to make any conclusions about policy variables except that researchers apparently do not feel these variables are likely to be important determinants of the NIPF timber harvesting decision. Though, as shown below, these policies appear to have a greater impact on reforestation and investment decisions than on harvesting decisions, which is consistent with their purpose.

4.1.3. Owner characteristics

The owner characteristics that are included in multiple studies include income, education/training, age, owner proximity to their forestland and a dummy variable for NIPF landowners that are also farmers. The results show that both income and age are generally found to have a significant negative effect on harvesting. A negative sign for income supports the notion that NIFP landowners are maximizing utility, which may include the amenities of a standing forest, rather than profits from timber harvests. The negative influence of age, however, may reflect landowner intentions to provide standing timber as a bequest to their heirs. In addition, landowner education/training was found to have increase harvesting in 60% of the models in which it was included.

4.1.4. Plot/resource conditions

Plot size and growing stock are the plot/resource variables most commonly included, with each appearing in 55% of NIPF timber harvesting studies included in this review. The results are generally as expected, with 82% of studies including plot size and 73% of those containing growing stock finding a significant positive effect of these variables on harvesting. In addition, there are several other variables that have been included in some studies, including measures of amenities/recreational opportunities, site quality, accessibility of roads and biodiversity of trees. It is expected that the quality of forest amenities/recreational opportunities and biodiversity of trees will both have a negative influence on the harvest decision, while higher site quality (as proxied by e.g. slope, timber productivity) and the accessibility of roads will increase harvesting. All four of these variables generally have the expected sign. The only exception is for measures of amenities/recreation opportunities, in which Lee (1998) finds that the presence of certain ecosystem amenities seems to increase harvesting. Each of these variables is significant in 60% or greater of the studies in which they are included.

4.2. A vote count of reforestation

In the same format as used for timber harvesting, Table 3 summarizes the vote counting results for the empirical reforestation literature. Market drivers and policy variables are most often included in models of reforestation (88% for each), followed by owner characteristics (53%) and plot/resource conditions (35%). Among individual variables, the most commonly included are government cost sharing, planting costs and sawtimber prices[9], present in 80%, 65%, and 59% of the empirical models, respectively.

Based on the percentage of studies that included a given category of variables that found a significant influence, the ordering of categories becomes policy variables (100%), market drivers (87%), plot/resource conditions (50%) and owner characteristics (44%). As far as the direction of these effects, there is very little disagreement among the reforestation studies analyzed. In fact, the only variable for which there is an inconsistency in sign between studies (considering only statistically significant estimates) is land value. It is only included in four studies and two find positive effects, one finds a negative effect and one does not find the influence of land value to be significant. This is not surprising, given the uncertain predictions about its influence on reforestation (see Kline et al. (2002) and Lee et al. (1992) for details).

Among individual variables, government cost sharing and technical assistance are most consistently found to positively influence reforestation. Cost sharing is positive and significant in every study that examines whether it has an effect on reforestation overall (12 of 14 studies that include it). Other variables that are found to be statistically significant in over half of the models that included them are pulpwood prices (80%), short-term interest rates (typically defined as the interest rate on 3-month treasury bills) (80%), land value (75%), tax incentives (67%), site quality (67%) and planting costs (64%). At the other end of the spectrum, owner age and a dummy variable for farming as landowner occupation are not significant in any of the reforestation studies.

4.2.1. 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 expected 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, but are statistically significant in only 69% of the studies that include price.[10] Generally, investigators include either the sawtimber price or the pulpwood price (or expectations of those prices), 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 pulp-

[9] The reforestation studies were typically more specific about the prices that they used in the model than harvesting studies, allowing results to be reported for sawtimber and pulpwood prices separately.

[10] 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., nine of 13 studies.

Table 3
Variables affecting NIPF reforestation behavior

Study	Market drivers							Policy variables			Owner characteristics			Plot/resource conditions	
	Saw prices	Pulp prices	Planting costs	Real ag crop price index	Land value	Interest-short term	Interest-long term	Cost share	Assist	Tax incentives	Income	Age	Farmer	Plot size	Site quality
Alig (1986)							0	+			+				
Brooks (1985)–Southeast	0		0					+							
Brooks (1985)–Southcentral	0		–					+							
Cohen (1983)	+		0	0			0	+			0				
de Steiguer (1984)	0					–		[a]			+				
Hyberg and Holthausen (1989)	+		–		0			+	+		0		0	0	
Kline et al. (2002)		+	–		+			+							
Kula and McKillop (1988)	+			–	–			+							
Lee et al. (1992)		+	–		+	–		[a]							
Lee and Murray (1990)	+		0							+				+	
Löyland et al. (1995)								+	+			0		+	+
Miranda (1989)						–	+	+			0				
Newman and Wear (1993)	+	0	–												
Royer (1987)	0	+	–					+	+		+		0	0	
Royer and Moulton (1987)		+	0					+	+	+	+		0		
Zhang and Flick (2001)	0		–			–	0	+	+	0	0	0		0	0
Zhang and Pearse (1997)														+	+
Included	10	5	11	2	4	5	4	12[b]	5	3	8	2	3	6	3
Significant	5	4	7	1	3	4	1	12	5	2	4	0	0	3	2
Positive	5	4	0	0	2	0	1	12	5	2	4	0	0	3	2
Negative	0	0	7	1	1	4	0	0	0	0	0	0	0	0	0
Not Significant	5	1	5	1	1	1	3	0	0	1	4	2	3	3	1
Percent Included	59%	29%	65%	12%	24%	29%	24%	80%[b]	29%	18%	47%	12%	18%	35%	18%
Percent significant (Included studies)	50%	80%	64%	50%	75%	80%	25%	100%	100%	67%	50%	0%	0%	50%	67%
Percent significant (All studies)	29%	24%	41%	6%	18%	24%	6%	80%[b]	29%	12%	24%	0%	0%	18%	12%

[a] Cost sharing is included in the models for these papers, but in the context of its effect on non-cost shared private tree planting only. Thus, the coefficients from these studies are being used to test for crowding out of private investment rather than the effect of cost sharing on total reforestation.

[b] For the purposes of this review, only those studies that were testing whether cost sharing had an impact on overall reforestation (15/17 studies) were included in the calculations.

wood prices, while Newman and Wear (1993) found just the opposite.

As in the case of timber harvesting studies, the percentage of reforestation studies that find a significant influence of price is lower than expected. It is quite possible that the variables used to represent expected prices do not adequately reflect actual landowner expectations of price at harvest, reducing the explanatory power of expected timber price.[11] Alternatively, it may be that capital constraints (alleviated by higher income and/or government subsidies) are a more important determinant of reforestation than expected price. 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 income is significant in only 56% of the studies that include it if it is an important measure of capital constraints. It may be the case that government programs are reducing capital constraints faced by landowners sufficiently that the influence of personal income on reforestation is attenuated. It is also possible that income is correlated with knowledge about cost sharing and technical assistance programs and use of these programs, causing the coefficient on income to be biased towards zero when government programs are also included.

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 reforest less, choosing instead to allow their forests to regenerate naturally (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 64% of studies that included this variable. 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.[12] 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 five studies included short-term interest rates in their econometric models, but four of them found significant negative effects on reforestation.

Another potential substitute for investments in forestry is to convert the land to agriculture or developed land. Both Cohen (1983) and Kula and McKillop (1988) include agricultural price indices to represent alternative investments in agriculture, but only Kula and McKillop (1988) find the expected significant negative effects of agricultural prices on reforestation. There are a relatively large percentage of studies including some measures of the opportunity cost of investing in forestry that find a significant influence on reforestation (73% across short-term interest rates and agricultural crops price index and land values). This suggests that researchers should consider including a measure of returns to alternative investments in their models. The opportunity costs associated with forestry investment have been omitted from the majority of reforestation studies, but both theory and empirical evidence suggest that they may be an important determinant of management activity.

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 neg-

[11] One of the reviewers pointed out that because much of the data used in these studies is collected through landowner surveys, the landowners could be asked about their price expectations. However, we are not aware of any researchers that have attempted to collect this information from NIPF landowners and use it in at least a published study of reforestation.

[12] Short-term interest rates are typically represented by the interest rate on 3-month treasury bills, while long-term rates are typically represented by the interest rate on 10-year treasury bonds.

ative impact and the other two do not find a significant influence of long-term interest rates.

4.2.2. 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. 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] Only two of the 14 studies do not find a statistically significant positive effect—de Steiguer (1984) and Lee et al. (1992). This is because both are studying the extent to which government cost share can crowd out private investment rather than the impact on total reforestation. 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. All of the studies that included technical assistance found a significant positive effect on reforestation. In addition, two of the three studies that included variables for tax incentives found a positive influence on reforestation.

4.2.3. 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 an indicator variable for NIPF landowners that are also farmers 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 government programs have reduced capital constraints such that income is not a primary determinant of reforestation investment. It may also be the case 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.

4.2.4. Plot/resource conditions

Finally, plot/resource variables were included in 31% of the models. The variable used most commonly (five studies) was plot size, which was found to be positive and significant in 60% of the papers in which it was included. This finding likely reflects economies of scale in reforestation. Alternatively, plot size could be capturing characteristics of the owner (e.g. wealth, interest in forest production, etc.). 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, but naturally regenerate balsam and hemlock, presumably a finding limited to their study area.

4.3. A vote count of timber stand improvements

Table 4 presents the findings of empirical research studies examining TSI. The factors included in these models are the same as those used for harvesting and reforestation at the broad aggregate level, including: market drivers, policy variables, owner characteristics and plot/resource conditions. However, there is much less reliance on market drivers to explain TSI and more emphasis on owner characteristics and plot/resource conditions. Both owner characteristics and plot/resource conditions are included in 100% of studies, while market drivers and policy variables

[13] de Steiguer (1984) and Lee et al. (1992) both included a variable for cost sharing and did not find a significant effect, but the dependent variable was private capital invested in tree planting rather than total investment in tree planting. Cohen (1983), in one version of the model estimated in her paper, used non-cost shared NIPF acreage planted as the dependent variable and finds the coefficient on cost sharing to be negative. In none of these cases do the results imply that cost sharing is not effective for increasing total reforestation, only that government cost sharing may or may not be crowding out private investment in reforestation.

Table 4
Variables affecting NIPF silvicultural treatment behavior

Study	Economic drivers			Policy variables			Owner characteristics				Plot/resource conditions	
	Saw prices	Interest rate-short term	Interest rate-long term	Cost share	Assist	Tax incentive	Income	Age	Educ training	Proximity to forest	Plot size	Site index
Boyd (1984)	+			+	+		0		+	+	+	
Löyland et al. (1995)				–	+			0	+	+	+	+
Romm et al. (1987)							+	–	0	0	0	
Zhang and Flick (2001)	0	0	0	[a]	0	+	+	0	0		0	0
Zhang and Pearse (1996)	0	+									0	+
Included	3	2	1	2[b]	3	1	3	3	4	3	5	3
Significant	1	1	0	2	2	1	2	1	2	2	2	2
Positive	1	1	0	1	2	1	2	0	2	2	2	2
Negative	0	0	0	1	0	0	0	1	0	0	0	0
Not significant	2	1	1	0	1	0	1	2	2	1	3	1
Percent included	60%	40%	20%	50%[b]	60%	20%	60%	60%	80%	60%	100%	60%
Percent significant (Included studies)	33%	50%	0%	100%	67%	100%	67%	33%	50%	67%	40%	67%
Percent significant (All studies)	20%	20%	0%	50%[b]	40%	20%	40%	20%	40%	40%	40%	40%

[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.

[b] For the purposes of this review, only those studies that were testing whether cost sharing had an impact on overall TSI (four/five studies) were included in the calculations.

are included in 60%. The variable most likely to be included is plot size, which was included in 100% of studies.

There is a wide variation across studies in the variables that are included. No variable is significant in more than two 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 conclusions are somewhat limited by the small number of econometric studies on TSI. Nonetheless, we feel it is useful to present findings from these studies using the same framework as for harvesting and reforestation. In addition, the recognition that economic modeling of TSI is less developed than other aspects of NIPF management may inspire additional much-needed research on this topic.

4.3.1. 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. Short-term interest rates were included in two studies and were found to have a significant positive effect in one and no significant effect in the other. A positive effect of short-term interest rates is counterintuitive. 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.

4.3.2. 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 except for technical assistance in Zhang and Flick (2001). By and large, these variables have the expected positive effects. That is, in 67% of the cases cost sharing, technical assistance and/or tax incentives encourage 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 follow up management activities. However, this is presumably an artifact of the dependent variable, at least in Zhang and Flick's analysis.[14]

4.3.3. 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.

4.3.4. 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 two 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. A meta-summary of NIPF management

Our review categorizes the influences on harvesting, reforestation and silvicultural treatments into four primary factors: market drivers, policy variables,

[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.

owner characteristics and plot/resource conditions. Combining the results of the meta-analysis for all NIPF management studies included, we find that market drivers are the most commonly included of these factors (88% of all studies), followed by plot/resource conditions (69%), owner characteristics (62%) and policy variables (58%). However, when we look at the proportion of studies that find statistical significance for these factors among the subset that include the factor, the ordering is almost reversed. Although least likely to be included, policy variables are most likely to be significant when they are included (87%), followed by plot/resource conditions (79%), owner characteristics (77%) and market drivers (73%). The fact that market drivers are the least likely of the four factors to be significant determinants of NIPF management behavior—although there is not a large difference between the four categories—is nonetheless surprising. It implies that changes in price, forestry costs and interest rates may not necessarily have the expected result. The use of government policies, however, appears to be an effective way of encouraging NIPF management activities, especially reforestation.

One possible explanation for the relatively low significance of some of these factors is the type and quality of data that has been used in prior research on NIPF management. For instance, as indicated above, the extent to which a current market price represents an expected future price in the landowner's eyes is subject to great uncertainty. On the contrary, the existence of government programs and the characteristics of the landowner and the site are known with a fair amount of certainty. The difference in precision with which these variables are measured may partly explain the lower statistical significance of some market variables. However, some data problems persist across all categories, including 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. However, 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 an independent variable's marginal effect on a dependent variable. 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 independence 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 researcher's lack of interest in publication. Finally, the inherent nature of economic and other social science 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.

Another consideration is that the majority of studies were conducted using data from the Southern US. Although we found some studies from the Northeast US, Europe and Canada, to the best of our knowledge, this reflects the geographic distribution of available studies that use statistical models to examine NIPF management rather than an intentional focus on this region for the synthesis. The inclusion of all studies from all regions that met the criteria for this synthesis is intended to make the results as general as possible and we do find several results are similar across the different regions. Nonetheless, the South is getting a large weight in the meta-analysis, suggesting that care should be taken when applying the results of this synthesis outside of this region to ensure that landowners face similar management decisions to those undertaken in the South. Because the Southern US has a very large percentage of timberland controlled by NIPF landowners compared with other regions of the US and the world and this region has been supplying a growing percentage of US timber, the results of this synthesis should be of great interest to researchers and policymakers regardless of geography.

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 harvesting, reforestation and TSI. 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. For instance, editors could require authors to report a basic number of descriptive statistics and marginal probabilities (if applicable), which would facilitate more sophisticated meta-analyses of NIPF management. 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.

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 increasing 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, 2003).

[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.

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[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% 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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