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Private Forest Investment and Softwood Production in the U.S. South

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Previous RPA assessments of timber production have placed high expectations on private forest lands in the South (Haynes 1990). In particular, they have anticipated that production from these lands will continue to expand as harvests are reduced in other parts of the country, especially on public lands. Any sustained increase in timber production, however, depends on investment in and the productivity of southern forests. This report examines the history of private forest investment and production in the South for two purposes. One is to define the aggregate effects of forest investment over the past 40 years. The other is to develop investment forecasts consistent with historical patterns of investment.

Investment generally is defined as the allocation of resources to future production. Accordingly, nearly every activity in forest management, including the absence of activity, can be interpreted as the outcome of an investment decision. Furthermore, activities which cause land to move into or out of forest cover influence the resources dedicated to future production. Depending on the relative importance of these factors, which may increase or decrease forest assets, total or net investment may be either positive or negative. All of these factors need to be accounted for in defining the aggregate effects of forest investment.

This report measures forest investment using an approach that addresses its multiple facets. All the influences previously mentioned are factored into the calculation of a single index, called a "forest capital index." This index provides a measure of how these forces have interacted over the forested landscape of the U.S. South. It measures how the total quantity of resources dedicated to timber production has changed between 1952 and 1992. It also provides some insights into how the quality of these timber-producing assets has changed.

This analysis of investment focuses exclusively on the private sector in the U.S. South (public lands contribute little to total production in this region), but examines lands managed by forest industries and by all other private ownership groups separately. Previous studies (e.g. Newman and Wear, in press) have shown, and this study confirms, that production behavior differs substantially between these two groups.[2] The focus here also is solely on softwood timber production.

Historical Changes

Softwood production in the South changed considerably between 1952 and 1992. The total area of softwood-producing forests declined, and the mix of plantation, natural, and mixed pine forest types changed substantially (Alig and Wear 1992). These changes reflect the countervailing effects of active investment in forest production and reduction in the land area dedicated to forest production. Also, the amount and mix of softwood forest products has changed. This section examines the effects of these various changes, and measures their combined influence on the region's capacity to produce softwood products.

There are two ways to measure the size of any production process. One is to measure the resources dedicated to production, in effect to measure the quantity of inputs. In forestry, total inputs are partially defined by the extent of forest area, forest conditions, and management intensity. Changes in the total inputs to forestry, over time, define the net effects of forest investment. Input growth indicates positive net investment; declines in the quantity of inputs indicates disinvestment. The other approach is to measure the outputs of the sector, in this case softwood pulpwood and sawtimber products. Output quantity provides an unambiguous measure of the current level of production, but does not, alone, say much about the future of production.

[2]Although differences between these two ownership groups have been studied in detail, relatively little attention has been paid to their interactions at a sectoral level. However, recent findings regarding the structure of timber markets (Murray 1992) indicate that there is the potential for strategic interaction.

The input and output sides of forestry, however, should be related; and, in the long term, should balance. Comparing inputs with outputs can provide insights into how the productivity of forestry has changed over time.

Forest Production: Investment and the Input Side

There are two types of inputs to forest production. One is the primary inputs of capital, labor, and land used to establish new forests. The other is the growth of existing forests. In effect, forests are capital assets which may be augmented either by investment (planting) or by physical appreciation (growth). Forest capital also is subject to depreciation by predation and fire, or by the conversion of land from forestry to other uses. In the analysis that follows, net growth (or decline) in forest capital is measured by accounting for both primary or gross investment, and capital appreciation and depreciation. Measuring gross investment is straightforward; but, measuring capital appreciation and depreciation is complicated by the variety and dynamics of forest conditions.

Previous studies of investment focused exclusively on gross investment in timber production in the South (Brooks 1985, Boyd 1984, deSteiguer 1984, and Cohen 1983). Within this literature, special emphasis was placed on studying the influence of substantial government programs aimed at expanding forest production or contracting agricultural production, especially on highly erodible lands, using tree planting. These studies generally found that programs cause forests to be planted, but fail to reach consensus on what the increased plantings mean for timber production over the long term. Other studies have examined whether planting programs merely transfer planting expenditures from the private to the public sector (Lee et al. 1992), and have examined the distributional consequences of planting programs (Boyd and Hyde 1989).

Unlike the preceding work, this study does not focus exclusively on gross investment and the impacts of policy on gross investment. Rather, gross investment, in the form of planting, is considered as only one contributing factor to net investment (or disinvestment) in forest production. Instead, the focus here is on measuring change in total forest inputs over time, including the effects of physical appreciation and depreciation of forest assets. By focusing on net investment, this study examines whether investment activities actually have expanded the capacity for softwood forest production in the region.

Methods

Measuring the total resources dedicated to forestry requires translating forest area and forest conditions into a measure of forest capital. This is done by treating each type of forest as a kind of capital asset with an eventual maturity date. The value of each forest type changes from year to year, reflecting biological growth, depreciation (through mortality or predation), taxes, and capital gains (or losses). Capital gains are determined by changes in the value of forest assets caused by changes in the market prices of forest products. The total value of a forest asset then can be expressed using an annual rent equal to the implied cost of holding the stand for 1 year (essentially an opportunity cost). The annual rent of different forest assets, therefore, defines their relative productivity in financial terms. These relative productivities then can be used as a set of weights for aggregating different forest assets into a measure of total forest capital.

This measure defines the total capital input to forest production in each year. For this study, the South's softwood-producing forests are broken down into three forest types (planted pine, natural-pine, and mixed pine-hardwood as shown in figure 1), and their approximate age class groupings. For each forest type/age class category, the annual forest rent, based on forest product prices etc., is computed for each year (1952-1992), and the rent-weighted forest capital is calculated. Year-to-year changes in capital value then are combined with the cost of gross forest investment (planted acreage times regeneration cost) to estimate changes in the resource input to forest production.

Forest capital may increase or decrease from year to year, depending on the relative impacts of appreciation and depreciation during that period. To gauge change in input, forest capital is measured as an index number with the base year set at 1952, so that the index measures proportional change from its value in 1952. This measure of input is herein referred to as the "forest capital index." Details on all of these computations and data can be found in Appendix A and in Wear (in press).

The forest capital index measures how the amount of resources dedicated to forest production has changed over time. Additional insights can be developed by

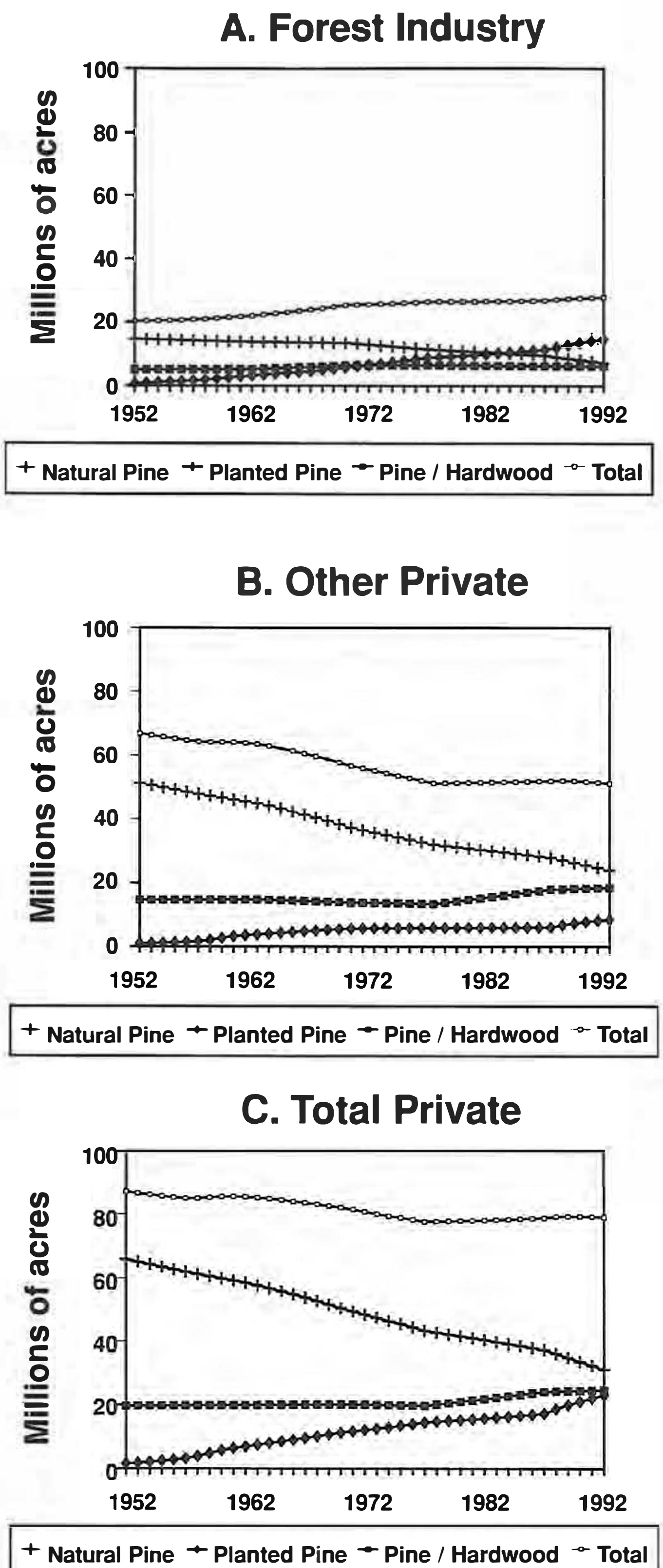

Figure 1.-Area of softwood-producing forests by forest type and ownership group (1952-1992).

Table 1.—Annual rates of change (percent) in acres of forest types by ownership groups in the U.S. South, 1952-1992.[1]

Forest type	Industry	Other private	Total
Natural pine	-1.76	-1.88	-1.85
Mixed pine-hardwood	+0.54	+0.59	+0.58
Pine plantations	+8.05	+5.95	+7.06
Total	+0.81	-0.66	-0.23

Computed by solving: $A_{52} (1 + r)^{1992-1952} = A_{92}$ (where A_t is the acreage at time t) for r.

comparing changes in the forest capital index with changes in the total area of softwood-producing forests. The difference between rates of change in capital and land area measures a "capital composition effect," which defines how the average quality of forest assets (in effect, the capital:area ratio) has changed over time. For example, if the quantity of capital increases faster than the area of forest, this implies that the average quality of forest land (in financial terms) has improved. This would be the case if management was intensified on a constant land base.

Results

Figure 1 shows how the area of softwood-producing forest and the mix of forest types in the South changed between 1952 and 1992 (see Alig 1986, for a detailed discussion of land use changes in the region). The total area of softwood-producing forest types declined at an average annual rate of 0.2% (see table 1 for rates of change by forest types and total land area). However, this aggregate decline masks an increase in the amount of forest held by the forest industry (+0.8% per year) and a countervailing decrease in forest area on all other private lands (-0.7%). Aggregate changes also mask some shifts between forest types. The acreage of pine plantations grew substantially on both ownerships. With industry and other private ownerships expanding plantation area at average annual rates of +8.1% per year and +6.0% per year, respectively, the total area of pine plantations in the South increased thirteen-fold between 1952 and 1992. In contrast, the total area of mixed pine hardwood was relatively stable, implying that the increase in planted pine was substantially offset by declines in the acreage of natural pine. The area of natural pine forest declined on both the industry ownership (-1.8% per year) and the other private ownership (-1.9% per year).

The forest capital index (table2) shows that aggregate input, like raw forest area, grew substantially on industry lands between 1952 and 1992. The total quantity of inputs to forestry on this ownership increased at an average annual rate of 1.14%, and exceeded the rate of expansion in total forest area. The resulting positive capital composition effect (+0.33%, table 2) indicates that the average quality of forest assets held by industry improved between 1952 and 1992. This reflects considerable growth in the proportion of forest lands under plantation management.

On forests held by other private owners, however, forest capital declined between 1952 and 1992 (-0.89% per year). Furthermore, this rate of decline exceeded the rate of decline in the total area of forest land. The resulting negative capital composition effect (-0.23% per year) indicates that the quality of forest assets also declined over the past 40 years. Although the area of pine plantations increased, these investments did not fully offset strong declines in the natural pine type and the net loss of pine-producing forest area.

The combined effect of net investment on industry lands and net disinvestment on other private lands was an essentially constant level of forest inputs across the sector between 1952 and 1992 (the middle line in figure 2). This indicates that, over this 40-year period, investments in forest plantings just offset the impacts of harvesting, and land use and forest type changes, and that total inputs to forestry did not change substantially. Instead, it shifted from land-extensive management on other private lands to more intensively managed industry lands. Also, countervailing capital composition changes for the two ownerships net out to a small, but positive, shift in asset quality across the private sector as a whole.

Average changes over the 40-year period provide a summary of investment history, but they also mask some important changes within the period. The chart of the forest capital index by ownership (fig. 2) illustrates the patterns of change between 1952 and 1992. Change on the other private ownership can be divided into three epochs. During the 1950s, net investment was slightly positive for the other private ownership. This, the only period of growth in forest capital for the ownership, coincides with substantial Soil Bank afforestation programs. The second epoch, commencing at about 1960, and continuing through the late 1970s, is characterized by a sustained decline in forest capital. During this period, cost-share programs for forest planting were in place (the Agricultural Conservation Program and Forestry Incentives Program); but, these were not strong enough to offset the effects of land-use change. The third epoch is characterized by a generally stable level of forest capital. In the last 5 years of the period however, forest capital declined slightly, while the area of planted pine increased. This is explained by strong declines in the reported area of natural pine. However, the data for this period, which coincides with the substantial Conservation Reserve afforestation programs, are preliminary, and considerable caution should apply to interpretations of these (1987-1992) results.

The forest capital index for the industry ownership shows steady growth through the mid-1980s followed by a leveling off in the remainder of the historical period (the same caveat applies to interpreting capital measures over the last 5 years of the series). Perhaps the most striking aspect of figure 2 is that investment by forest industry is generally a mirror image of investment on other private lands (with the exception of the 1950s).

Table 2.—Annual rates of change for pine-producing land, forest capital, and the capital composition effect in the U.S. South, by ownership group (1952-1992).

Quantity	Industry	Other private	Total
Total acres	+0.81	-0.66	-0.23
Forest capital	+1.14	-0.89	-0.15
Capital composition effect	+0.33	-0.23	+0.08

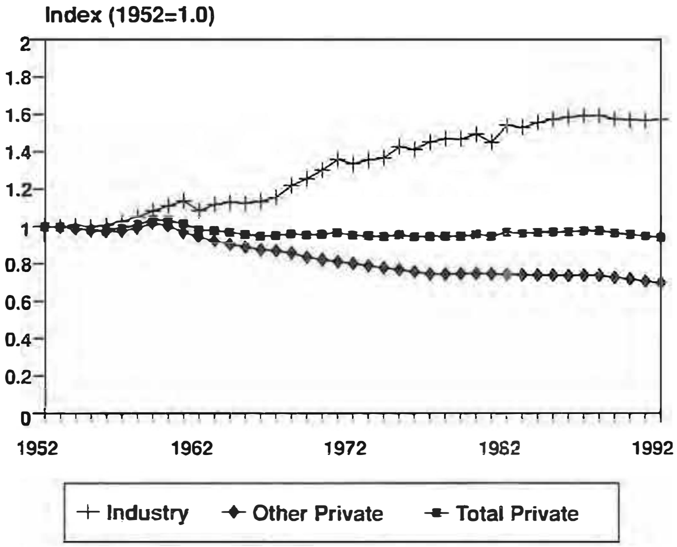

Figure 2.-Forest capital indices for the U.S. South by ownership group and in total (1952-1992). The indices have a base year of 1952.

Again, the result is an essentially constant forest capital index for the private sector as a whole (the middle line in figure 2) throughout the 40-year period.

Forest Production: The Output Side

Another measure of the size of forest production is its output. Although measuring output is generally more direct than measuring inputs, it still is nontrivial. Calculating a measure of change in total output that is comparable to our measure of total input requires aggregating changes in multiple outputs across time. This requires weighting the contribution of forest outputs in economically meaningful terms. The resulting total output index defines change in total output in a way that is comparable to the measure of input provided by the forest capital index.

The total output index is formed from its component parts by weighting each output by output revenues. The component outputs are softwood sawtimber and softwood pulpwood production for the two ownership groups (industrial and other private). This is directly analogous to constructing the forest capital index with product prices taking the role of the forest rents. However, while inputs were measured for the period 1952-1992, output measures could not be extended beyond 1985 because of data limitations. Details on the output index also are contained in Appendix A and Wear (in press).

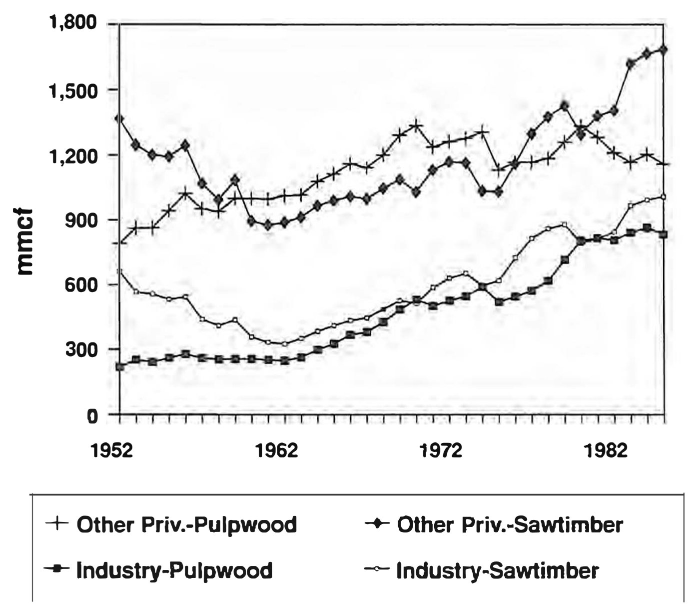

Figure 3.-Softwood production by product class and ownership group (1952-1985).

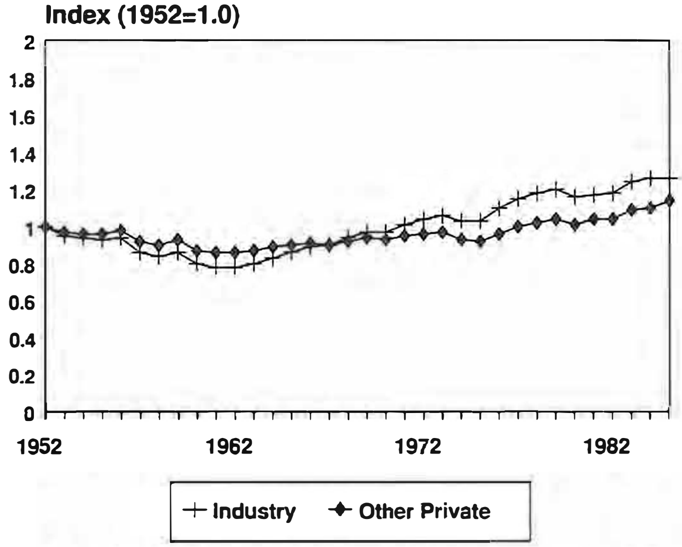

Figure 4.-Total softwood output index by ownership group (1952-1985). The indices have a base year of 1952.

Figure 3 shows trends in sawtimber and pulpwood production for both ownership groups between 1952 and 1985. Although softwood sawtimber production declined substantially between 1952 and 1960, since then, both products from both ownerships have trended generally upward. The only exception is pulpwood production from other private forests, which has been relatively stable since the early 1970s.

The total output index charted in figure 4 also reflects these general trends. Although total output dips somewhat between 1952 and 1962, total production on both ownerships has trended upward subsequently. The output growth rate on industrial lands over this period has been especially strong. At 2.1% per year, it has outstripped output growth from other private lands (1.2% per year) by about 75%.

Productivity: Comparing Input and Output Measures

Because forest capital measures input to, and forest product measures output from the same production process, the two indices should be directly comparable. What does it mean when they are different? The difference between growth rates for total output and total input measures change in the output:input ratio, and, therefore, provides a measure of change in the relative productivity of inputs.[3] For example, if output grows faster than input, this suggests that the productivity of inputs has increased.

[3]The output:input ratio developed here can be considered a financial version of the familiar growth:drain ratio (actually its inverse).

One plausible explanation for a changing output:input ratio is change in the underlying forest production process. The forest capital index is based on a set of (time-invariant) empirical yield tables. If actual yields had improved over time, then realized output growth would have been greater than the input growth estimated with these yield tables. This, however, is not the only plausible explanation; and it is important to emphasize that differences between output and input growth are unexplained growth residuals, which are difficult to sort out for forestry (Wear, in press). Change in the aggregate productivity measure may be attributed to any number of causes. It is perhaps best to view this definition of productivity as simply a measure of the output growth that cannot be explained by our model of input growth.

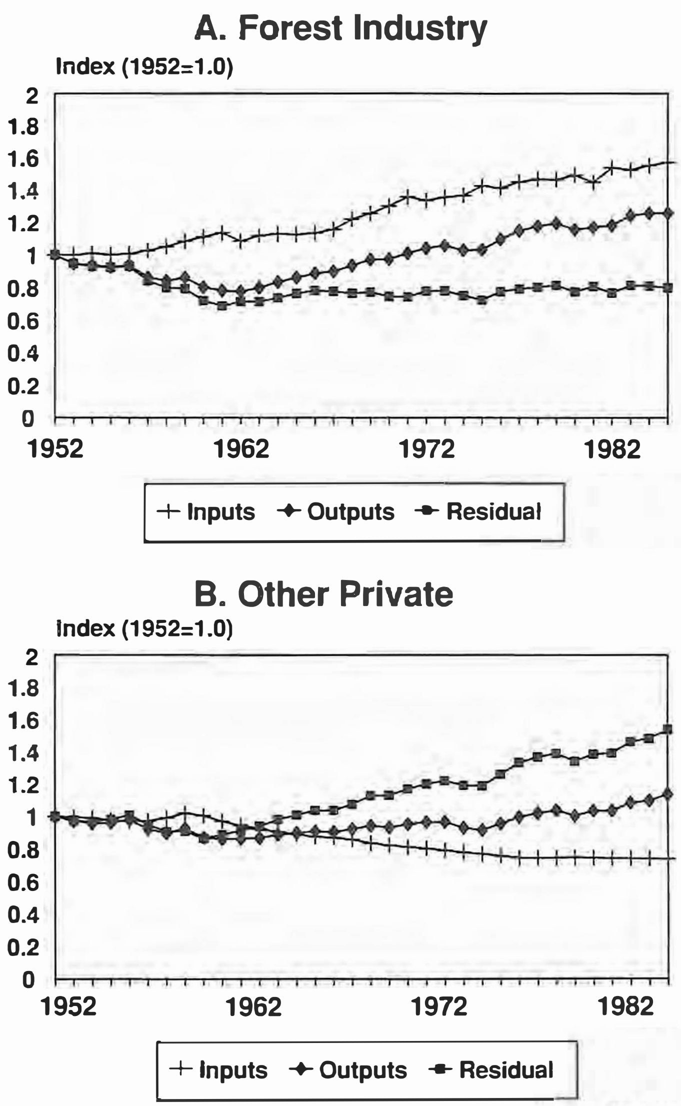

Figure 5.-Forest capital (input), output, and productivity indices by forest ownership group (1952-1985). Indices have a base year of 1952.

Figure 5 charts differences in the growth rates of forest capital and forest product, for the two ownership groups. A positive slope indicates increasing productivity; a negative slope indicates declining productivity. Between 1962 and 1985, the output:input ratio expanded for both ownerships. However, the differences between the two groups was substantial. While the rate of growth was about 0.5% per year for the industry, it was nearly four times as high for the other private ownership group (2.1% per year). Therefore, while capital and output growth tracked quite closely for the forest industry, other private lands produced increasing output from a declining quantity of inputs, defining a large productivity residual.

Although productivity growth for the industry is generally consistent with other studies of aggregate productivity change in the U.S. South (Newman 1991), the strong productivity finding for other-private lands is much higher than previously found. This strong growth in productivity is not likely to be explained by shifts in forest yields. Instead, because management generally has been less intensive on other private lands, we would anticipate yield improvement to be higher on the industry lands. Another, more plausible explanation of this high value for other private lands rests on the measure of timberland which underlies the input index.

Forests are classified as timberland based solely on physical criteria, without consideration of the actual intent of the landowner. To the extent that some landowners do not actually use timberland to produce timber, then forest surveys overestimate timberland acres. This would not necessarily bias the forest capital index, as long as the proportion of timberland actually managed for timber production remained relatively constant over time. However, increasing output:input ratios may indicate that the share of measured timberland actually managed for timber production has changed between 1952 and 1985.

The steady growth in output from a declining other-private land base might be a source of encouragement to policy analysts and wood-using firms concerned about the future of timber supplies in the U.S. South. Conversely, expanded output from declining inputs could suggest unsustainable harvest levels. Although recent stability in inputs on other private lands may allay concerns regarding sustainability, these results emphasize that the productivity measure is a residual unexplained by measured inputs and outputs. It, therefore, defines a gap in our accounting of forest investment and production, and highlights an important need for additional data collection and research (see Wear, in press, for additional discussion of this topic).

Forecasting Investment

The basic problem for forecasters is that they must construct a future in order to forecast it. That is, a forecast can be made only after making a number of assumptions about future conditions. This section describes the forecasting of forest investment and the accumulation of planted pine area in the U.S. South, for nearly 50 years into the future. Clearly, forecasts of this length are doomed to be unrealized; but, the intent of this analysis is simply to simulate the operation of historical behaviors on anticipated trends. The set of assumptions generally comes from other components of the RPA Assessment, and the results are intended to inform analysis within the context of the RPA Program.

The historical assessment of inputs to forestry indicates that, although forest planting has been extensive in the South, it has not expanded the size of forest production over the past 40 years. Instead, it has served largely as replacement investment, offsetting the effects of harvesting and land-use conversions. Although total input levels have been constant, they have shifted from other private to industry ownership groups. However, over the past 15 years or so, input levels generally have leveled off for the two ownerships as well. This long-term stability of inputs to timber production (the forest capital index) provides the basis for forecasting future planted pine acres.

The value of historical observation in describing future activities depends on correspondence between historic and future conditions. One area where conditions appear to have changed considerably in the recent past is agriculture, the other major land-using sector in the South. Agricultural markets and policies considerably influence land use in the region. Recent reforms in national agricultural policy both discourage converting forests to other agricultural uses and promote afforestation on marginal crop and pasture lands. These types of policies have reduced an important force behind disinvestment in forestry on other private lands, and may explain the most recent stability of forest input levels. Assuming that these forces will persist suggests that input levels will remain stable on both industry and other private lands, consistent with the most recent trends.

This assumption would imply further that, for both ownerships, any future growth in output would have to come from expansions in productivity. This is difficult to predict, especially because productivity is measured as an unexplained residual, and because of the data issues raised earlier regarding the other private ownership. However, productivity has grown consistently on both ownerships, especially on other-private lands. This suggests that continued growth in output, at least in the short term, might be possible under this scenario.[4]

The forest capital index is derived from the areas of natural pine, mixed pine-hardwood, and planted forest types. Projecting change in planted area requires some assumptions about how natural pine and mixed pine-hardwood area also will change. We assume, based generally on findings from the 1989 RPA Assessment (Alig et al. 1990), that the area of natural pine and mixed pine-hardwood will decline at annual rates of 1.5% and 0.2%, respectively. In addition, the ratios of land rents between forest types (based on relative product prices and management costs) are assumed to remain essentially constant into the future.

This scenario defines only one of a large number of plausible futures for the softwood-producing sector in the U.S. South. It projects forest planting under a continuation of historical investment patterns, which have kept forest inputs relatively constant over the past 40 years. It also assumes that input levels for the two ownership groups will remain constant. However, this is based on the most recent history of investment. Before leveling off, industry sustained input growth from about 1960 until the mid-1980s. We consider the possibility that this leveling of inputs on industry lands, observed over the past 10 years, is a short-term phenomenon, and consider a second scenario (scenario B) which holds forest inputs constant on other private lands but allows industrial inputs to grow at a moderate rate (+0.5% per year). As a result, total inputs also would grow, although at a relatively small rate, for the whole sector, under this scenario.

Forecast Results

The results of forecasts are summarized in table 3 and are graphed in figure 6. Although somewhat lower than previous projections for the region (USDA Forest Service 1988), plantation acres are shown to nearly double

[4]Although this strongly suggests continued growth in the short term, there is obvious folly in depending on an unexplained residual growth to continue in the long term.

by the year 2040. The changes in other forest types are defined by assumption, and they parallel projections from previous assessments: natural pine falls by 52%, and mixed pine-hardwood falls by 10% between 1992 and 2040. The total area of pine-producing forests is essentially constant, at 98% of its 1992 value in 2040.

For Scenario A, expansion of planted pine on other private lands would outstrip growth on industry lands. Although the ratio of industry to other private planted area was roughly 2:1 in 1985, the area of planted pine would be slightly greater on other private lands by 2040. These projections of planted area for the other private ownership are very similar to projections from previous assessments. However, scenario A's projection of total planted pine area (40 million acres in 2040) is somewhat lower than shown in the 1989 RPA Assessment (45 million acres). Results for scenario B, which forecasts moderate growth in forest inputs on industrial lands, however, are almost identical to the 1989 findings, with total planted pine area at 46 million acres in 2040.

What do these results imply for output from the sector? First, if input levels are held constant, then, without improvements in productivity, production should at least be stable. However, productivity gains—measured here as output growth unexplained by input growth—were substantial over the historical period. A continuation of these trends might be anticipated, at least for the short-term future, but with increasing un-

Table 3.—Forest area projections by management type, for the U.S. South 1985-2040, under scenario A. Numbers in parentheses are planted pine area projections for Scenario B.

	1992	2000	2020	2040
Industry				
Planted pine-A	14,585	15,422	17,139	18,426
Planted pine-B	(14,585)	(16,392)	(20,710)	(24,872)
Natural pine	7,155	6,340	4,686	3,464
Mixed pine-hardwood	6,149	6,051	5,814	5,586
Total	27,889	27,813	27,639	27,476
Other-private				
Planted pine	8,563	11,309	16,944	21,165
Natural pine	24,040	21,302	15,745	11,638
Mixed pine-hardwood	18,574	18,279	17,561	16,872
Total	51,177	50,890	50,250	49,675
All private				
Planted pine	23,148	26,731	34,083	39,591
Natural pine	31,195	27,642	20,431	15,102
Mixed pine-hardwood	24,723	24,330	23,375	22,458
Total	79,066	78,703	77,889	77,151

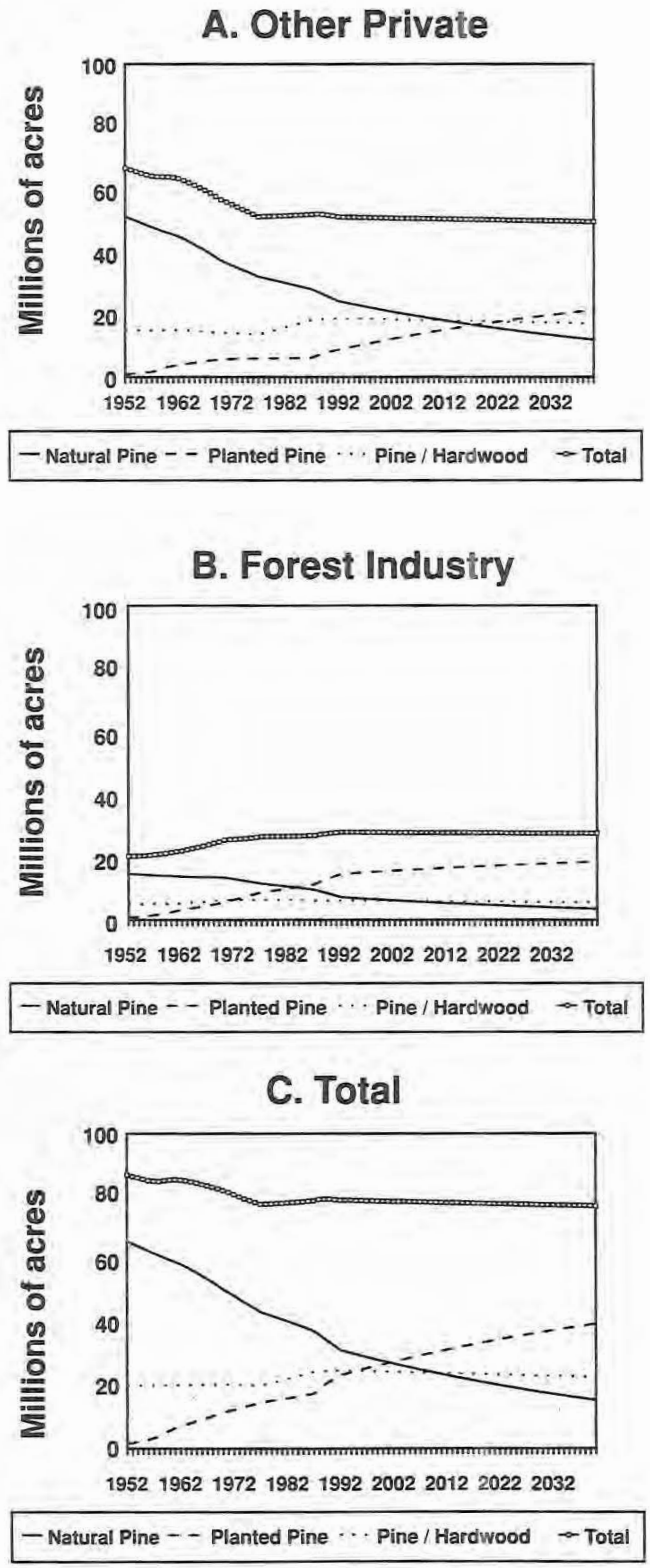

Figure 6.-Area of softwood-producing forests by forest type and ownership group (1952-2040). Forecasts (1993-2040) are for projection scenario A.

certainty over time, given the definition of productivity as an unexplained residual. Substantial productivity gains, especially those observed for the other private lands, are not likely to be sustained in the long-term.

Conclusions

The historical analysis leads to five conclusions.

1. An analysis of forest investment indicates that forest planting generally has served as replacement rather than expansionary investment in the South. That is, it has replaced forest capital lost by harvesting, land-use change, and mortality and predation, so that the total quantity of resources dedicated to forest production remained relatively constant between 1952 and 1992.

2. While measures of total input across the sector have been constant, industry expanded production by investment, while other private owners, as a whole, experienced disinvestment over the historical period. However, inputs essentially leveled off on both ownerships over the last 15 years of this period.

3. Although the product mix of forestry was changed, total output growth was steady since the early 1960s. The rate of growth for industry lands was substantially greater than that found on other private lands.

4. The productivity measure for industry lands, based on a comparison of input and output growth, was positive and generally consistent with previous research findings.

5. The productivity measure for other private lands was much larger than the measure for industry's lands, and was inconsistent with previous research. This could indicate a substantial expansion in the area of forests actually managed for softwood production on other-private lands. Conversely, it may suggest unsustainable harvests. Most clearly, it highlights the shortcomings of historical measures of timberland for the other private ownership group. These shortcomings limit the conclusions that can be drawn for this group, and define an area where fundamental data are missing from the analysis of timber supply.

Projections of planted pine acres lead to the following conclusions.

1. Continued expansion of planted pine area is consistent with the historical investment behavior of the private sector in the South.

2. Projections of planted pine area on other private lands are very similar to previous assessment projections.

3. Projections of planted pine area on industry lands, with input levels held constant—consistent with the past 10-15 years—are somewhat lower than previous projections. However, with a moderate rate of input expansion, consistent with the long-term history of investment, projections show increases very similar to the previous assessment findings.

Literature Cited

Adams, Darius M.; Jackson, Kathleen C.; Haynes, Richard W. 1988. Production, consumption, and prices of softwood products in North America: regional time series data, 1950-1985. Res. Bull. PNW-RB-151, Portland OR: U.S. Department of Agriculture, Pacific Northwest Forest Experiment Station. 49 p.

Alig, Ralph J. 1986. Econometric analysis of the factors influencing forest acreage trends in the Southeast. Forest Science. 32(1):119-134.

Alig, Ralph J.; Hohenstein, William G.; Murray, Brian C.; Haight, Robert G. 1990. Changes in area of timberland in the United States 1952-2040, by ownership, forest type, region, and state. Gen. Tech. Rep. SE-64. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southeastern Forest Experiment Station. 34 p.

Alig, Ralph J.; Wear, David N. 1992. Changes in private timberland: statistics and projections for 1952 to 2040. Journal of Forestry. 90(5):31-36.

Ball, V. Eldon. 1985. Output, input and productivity measurement in U.S. agriculture, 1948-79. American Journal of Agricultural Economics. 67:475-486.

Boyd, Roy G. 1984. Government support of nonindustrial production: the case of private forests. Southern Economics Journal 51:89-107.

Boyd, Roy G.; Hyde, William F. 1989. Forestry sector intervention: the impacts of public regulation on social welfare. Ames, IA: Iowa State University Press. 295 p.

Brooks, David J. 1985. Public policy and long-term timber supply in the South. Forest Science. 30(3):697-704.

Cohen, Melinda E. 1983. Public cost share programs and private investment in forestry in the South. In: Royer, J. P.; Risbrudt, C. D. eds. Proceedings, nonindustrial private forests: a review of economic and policy studies. Durham, NC: Duke University Press. 181-188.

de Steiuger, J. Edward. 1984. Impact of cost share programs on private reforestation investment. Forest Science. 30(3):697-704.

Haynes, Richard W. 1990. An analysis of the timber situation in the United States: 1952-2040. Gen. Tech. Rep. RM-199. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station. 268 p.

Lee, Karen J.; Kaiser, H. Fred; Alig, Ralph J. 1992. Substitution of public for private funding in planting southern pine. Southern Journal of Applied Forestry. 16(4):204-208.

McClure, Joseph P.; Knight, Herbert A. 1984. Empirical yields of timber and forest biomass in the Southeast. Res. Pap. SE-245. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southeastern Forest Experiment Station. 75 p.

Murray, Brian C. 1992. Testing for imperfect competition in spatially differentiated input markets: The case of U.S. markets for pulpwood and sawlogs. Durham, NC: Duke University. Ph.D. Dissertation. 167 p.

Newman, David H. 1987. An econometric analysis of the southern softwood stumpage market: 1950-1980. Forest Science. 33:932-945.

Newman, David H. 1991. A modified production function analysis of changing southern forest productivity. Canadian Journal of Forest Research. 21(8):1278-1287.

Newman, David H.; Wear. David N. [In press]. The production economics of private forestry: A comparison of industrial and nonindustrial forest owners. American Journal of Agricultural Economics.

U.S. Department of Agriculture, Forest Service. 1988. The South's fourth forest: alternatives for the future. For. Resour. Rep. 24. Washington, DC: U.S. Department of Agriculture, Forest Service. 512 p.

Vaseivich, J. Michael. 1988. Summary of timber land investment opportunities. [Draft manuscript.] North Central Forest Experiment Station, East Lansing, MI.

Wear, David N. [In press]. Measuring net investment and productivity in timber production. Forest Science.

Appendix A. Forest Capital and Forest Output Indexes

This section lays out the process used to develop an aggregate measure of the change in forest capital. It is based on a financially-weighted sum of forest acreage. The weights relate the expected revenues and costs of a variety of forest types and vintages to a period by period measure of forest rent. This is exactly the approach used by economists studying investment and productivity in manufacturing, in agriculture, and in the general economy. In these studies, the focus has been on aggregating capital, in the form of machinery, trucks, buildings, computers, etc., into a measure of total capital. In manufacturing, for example, the analyst must relate the productivity of a machine defined by the stream of services it will provide and the costs of repair and replacement, to a rent or service price for a given period. These provide the weights for summing across different classes of capital. The analogy is direct for forests.

The aggregation of capital depends on an accurate accounting of the service or rental price. The rental price for a type of capital is simply the cost of using it for a period of time and is related to how the value of the capital asset (i.e. the purchase price) changes over time. The concept of forest rent, an important part of the economics of forest management, is closely tied to the general definition of capital rents. In theoretical terms, capital rent is defined by the equation:

$$R = OC + D + T - CG \quad [1]$$

where rent (R) is equal to opportunity costs (OC), plus depreciation (D) and taxes (T), minus capital gains (CG) accruing to an asset for a specified period of time. Opportunity costs are measured as the costs of holding the forest for the period and are equal to the forest value times an alternative rate of return (OC = V r). Depreciation in forestry can be defined as the proportion of forest stocks lost to various hazards (d) times the value of the stock (D = V d). Capital gains are changes in the forest value resulting from changes in forest product prices or costs over time ($CG = V_t - V_{t-1}$). Taxes take the form of income or property assessments. If taxes are directly proportional to forest values they can be dropped from the analysis which follows. This approach is taken here; but, the study of differential tax influences is an important topic for future research.

The valuation of forest land (V) plays a crucial role here. It is defined as the expected returns to the forested acre, based on a biological growth function, prices, and costs. In addition, the valuation of capital usually entails a scrap value, for example, the salvage price of a machine at the end of its use. In forestry, the scrap value is defined as the return to future forest rotations (the bare land value, cf. the optimal rotation problem). Implicit in this view is that the scrap value of the forest is defined by its continued use in forest production.

The measurement of capital constitutes a broad field of inquiry in economics. Several indexing procedures have been proposed and studied in terms of their financial and physical production assumptions. One type of indexing appears to be the most general (i.e., it is accurate for the widest range of circumstances) and is the most widely used. It is based on the Tornqvist index (herein referred to as the T-index), which is used by the Bureau of Labor Statistics to measure capital inputs in the economy at large, and by several researchers studying individual sectors of the economy (e.g., for agriculture see Ball 1985). The T-index measures change in the total quantity of capital as the weighted sum of changes in each type of capital. The weights are cost shares based on capital (forest) rents. The rate of change in forest capital between periods t-1 and t is defined by the equation

$$F^* = \frac{1}{2}\sum_{i=1}^{n}(w_{i,t} + w_{i,t-1})A_i^* + w_{n-1}I^* \qquad [2]$$

where the rate of change in total capital (F^*) is defined by the sum of rates of change in each capital (forest) type(A^*_i), weighted by the average of cost shares for that capital type (wi) in the two periods, and the gross investment in planting (I^*) weighted by its cost share (w_{n+1}). By definition, these cost shares must sum to one.

To apply this index, we need to measure two types of variables. One is the acreage of each forest type and its age distribution in each period (which define the A^* in equation [2]). The second is a measure of forest rent for each of these forest type/age classes which defines the cost share terms (w_i) in equation [2]. For our area of study, the softwood-producing sector of the U.S. South, there are three relevant forest types: pine plantations, natural pine, and mixed pine hardwood.

The USDA Forest Service presents benchmark measures of the total timberland acreage for these forest types, when it conducts national resource assessments (about every 10 years). The benchmarks from the most recent RPA database are the basis for estimating annual acreage change in the South between 1952 and 1992. Acreage were interpolated between the benchmark years (1952, 1962, 1970, 1977, 1987, and 1992) using two methods. For plantations, we assumed that annual changes in plantations were directly proportional to the forest planting (gross investment) reported for the South (USDA Forest Service 1988). For natural pine and mixed pine hardwood types, we assumed that annual changes were directly proportional to softwood harvest quantities in each year. Using these methods, we defined the trends in forest area shown in figure 1, for the industrial and nonindustrial private ownership classes. A simple growth accounting method was used to define the age distribution of plantation acres. For the other forest types, half of the area was assumed to be uniformly distributed between the ages of zero and the optimal harvest age; and the other half was mature. Although a broad assumption, we had no better data source for this; and our analysis showed that results were not very sensitive to reasonable adjustments in this assumption.

To calculate rental prices for forest stocks, we used empirical yield tables constructed by Vaseivich (USDA 1988, based on the work of McClure and Knight 1985), for the study of timber investment opportunities in the South's Fourth Forest Report (USDA Forest Service 1988). In addition, we used a time series of softwood pulpwood and sawtimber prices, constructed by Newman (1987) for the South. A regeneration cost series, developed by Brooks (1985) and extended by (Lee et al. 1992), was used along with the price and yield data to evaluate each forest type and age, to define the forest value and optimal rotation age in each period for each forest type, using standard methods. Forest rental prices were derived from forest asset values using an aggregate internal rate of return based on a comparison of product revenues with total forest assets (see Wear, in press, for details on all computations).

The forest output index was also calculated using a Tornqvist index of forest products:

$$Q^* = \frac{1}{2}\sum_{i=1}^{l}[s_{i,t} + s_{i,t-1}]Y_i^* \quad [3]$$

where Q_* is the rate of change in total output, the s's measure the revenue share of product i in period t, and Y^*_i is the rate of change in the output of product i. Total quantities of and prices for the major softwood products, pulpwood and sawtimber, were developed by Newman (1987, data by personal communication). The share of production by ownership group was derived from Adams, Jackson, and Haynes (1988).

Appendix B. Projection Model

The productivity residual is defined by subtracting the rate of change in forest capital from the rate of change in forest output in each period. This relationship is the basis for a model which forecasts the acreage of plantation in response to assumptions about land area, output, and productivity changes. In effect, this method defines the plantation area, which is consistent with the historical development of the softwood-producing sector and these assumptions. The basic equation is

$$p^* = Q^* - F^*. \quad [4]$$

Substituting the equations for Q^*, the forest product index, and F^*, the forest capital index, the model is expressed in terms of the primary quantities:

$$p^* = \frac{1}{2}\sum_{i=1}^{l}[s_{i,t} + s_{i,t-1}]Y_i^* - \frac{1}{2}\sum_{j=1}^{l}[w_{j,t} + w_{j,t-1}]A_j^* - \frac{[w_{n+1,t} + w_{n+1,t} - 1]}{2}I^*. \quad [5]$$

To simplify terms, drop the time index, define the average cost or revenue share as a_i, and break out acreage by forest type (A_n is natural pine acres, A_m is mixed pine-hardwood acres, and A_p is plantation acres).

$$p^* = Q^* - \alpha_n A_n^* - \alpha_m A_m^* - \alpha_p A_p^* - \alpha_{n+1} I^* \quad [6]$$

By assuming that the rate of change in plantation acres and planting are equal equation [6] can be solved for the rate of change in plantation acres:

$$A_p^* = \frac{Q^* - p^* - \alpha_n A_n^* - \alpha_m A_m^*}{\alpha_p + \alpha_{n+1}} \quad [7]$$

This equation then is used to estimate the path of plantations, given assumptions regarding output growth, productivity change, and acreage change for natural pine and mixed pine-hardwood forests. The ratios of forest type prices and the ratios of product prices are assumed constant for the simulation period.

Wear, David N. 1993. Private forest investment and softwood production in the U.S. South. General Technical Report RM-237. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station. 12 p.

A capital accounting approach is used to measure the net effects of land area change, forest type conversion, and direct investment on timber assets in the U.S.South from 1952 until 1992. The resulting measure of net forest investment indicates asset growth on the lands held by forest industry but net disinvestment on all other private lands. Results also reflect uncertainty about investment and production from this latter group. The historical analysis informs projections of forest investment to the year 2040.

Keywords: Forest investment, timber production, forest economics, capital accounting, RPA.