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Economic Issues in Assessing Sustainable Development in Forestry

Terrence S. Veeman (with M.K. Luckert)

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Economic Issues in Assessing Sustainable Development in Forestry

by

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results point to important aspects of individual choice that should be accommodated in the design of forest management policies. There is a preference for more stable and less variable flow of benefits as well as for sequences with losses ahead of gains. Hegan and Luckert's examination of the effectiveness and feasibility of the allowable cut effect (ACE) mechanism was based on a timber supply model covering a 200-year planning horizon. The simulations indicate that positive returns to ACE occurred only when operating under harvesting constraints with a mature starting forest and for AAC calculations that ignored deciduous volumes. And the positive returns were higher for extensive, rather than intensive investments. Combining these results with other potential impediments to the ACE, Hegan and Luckert conclude that the probability of tenure holders having incentives to undertake ACE investments is low.

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INTRODUCTION

Sustainable management of Canada's forests requires more comprehensive measures of reference regarding forest resource use as well as an improved set of policies for the sector. The studies conducted under this project have attempted to tackle issues related to these aspects of sustainable forest management. The need for better measures of economic performance that reflect changes in social welfare, including environmental aspects, more accurately is now widely recognized. Conventional approaches to both productivity growth and national income ignore environmental effects and resource depletion. As a result, these approaches do not provide true measures of sustainability, profitability and competitiveness of the sector. The environmentally sensitive productivity (by Hailu and Veeman) and green accounting (by Pearson) components of this project address these issues within the context of the forest sector. Environmentally-adjusted productivity growth is, arguably, the single most important indicator and determinant of long run sustainability and yet it is not a CCFM indicator. The investigation into the public's time preference undertaken by Taylor suggests important patterns of choice that should be taken into account by a forest management scheme aiming at the exploitation of the forest as a public resource. The final component of this project (by Hegan and Luckert) examines the effectiveness as well as economic rationality of the allowable cut effect (ACE) mechanism that has been proposed as a way to intensify forest management efforts for the benefit of future generations.

Environmentally Sensitive Productivity Analysis

The studies conducted under this sub-project address important shortcomings in previous approaches to the measurement of productivity growth in forest industries. Conventional measures of productivity change concentrate on marketed inputs and outputs by ignoring changes in the environmental effects of economic activity. These conventional measures credit an industry for its production of marketable outputs but not for its use of inputs to produce improved environmental quality through pollution abatement. Thus depending on the actual trends in the industry, these conventional measures could overestimate or underestimate the true measure of progress that would be obtained if environmental effects like pollutant or undesirable outputs were incorporated into the analysis (Repetto et al. 1996). As a result, this shortcoming of conventional approaches to the measurement of economic performance could lead to misguided policy recommendations. For example, conventional analyses could lead to policies biased against investment in research and development by understating true productivity improvement in industries that have been devoting an increasing share of resources for pollution abatement activities.

Correction for changes in environmental effects is, therefore, very important in forest industries, which have significant environmental effects. The Canadian pulp and paper industry, for example, has been a significant source of water pollution, accounting for about 50 percent of the waste dumped into the nation's waters (Sinclair 1990). At the same time, this industry has spent large sums of money to reduce pollution output. As a result, the output of water pollutant and other pollutant from this industry have been reduced dramatically in the last four decades. Previous studies on the productivity growth of this industry have ignored these environmental benefits and thus do not provide an accurate picture of the performance of the industry over the last four decades. Similarly, studies on forest harvesting industries have followed the conventional approach. Moreover, previous studies on the forest harvesting industries have focused at the national level of aggregation without examining differences in the regional levels of technical efficiency. The productivity research undertaken under this project examined productivity trends in both the pulp and paper and the boreal logging industries using both conventional and environmentally sensitive approaches. The study on the boreal logging industry was also conducted at the regional level of analysis and attempts to explain differences in performance among the boreal regions using variables that reflect regional socio-economic and forest characteristics.

What is productivity?

Speaking broadly and informally, productivity is about how much we get in products or services out of the scarce resources we utilize. Productivity is one of the major things that economics is fundamentally about, whether the economizing is from the point of view of an individual, a firm, an industry, a nation, or the global economy as a whole. At the firm and industry levels productivity determines competitiveness and profitability. At the national and global levels, productivity is one of the most important determinants of standards of living. What appear to be small changes in productivity growth rates may compound over time to cause serious economic consequences. Thus there is no wonder that changes in productivity growth attract serious attention from economists, politicians, the business community and others.

What are the sources of productivity growth?

Productivity gains or losses occur due to at least the following three important factors:
changes in the degree of efficiency with which resource inputs are utilized,
changes in the state of the technology, and
changes in the scale of production

What are the problems with conventional approaches?

Since productivity is about how much we get out of the *scarce resources* we utilize, it is necessary to measure the outputs and inputs of our productive activities more comprehensively. Our scarce resources include not only the resources that are marketed but also non-marketed, unpriced or poorly priced components such as our *natural resources* and the *environment*. The problem with conventional measures of productivity growth (as well as conventional approaches to national income accounting or economic analysis in general) is that our natural resources and the environment are treated as 'external' to the economy and ignored. Conventional measures depict distorted pictures of true productivity growth and the sustainability of our economic activities. They can lead to misguided policy choices. Therefore, we need environmentally-adjusted productivity measures that focus not only on marketed inputs and outputs, but also on proper accounting for the utilization of our natural resources as inputs as well as the use of the environment as a recipient of the 'undesi
pollutant outputs of our activities.

Macro-economic Sustainability Indicators

Recently efforts have been made to include environmental and natural resource depletion in economic income accounting measurements. Various “rules” for sustainable development have been put forward in recent years, but none of these can be readily operationalized. This leaves the next best alternative of tracking our progress toward a sustainable path using indicators of sustainability. Macro indicators of sustainability have the advantages of relatively broad applicability and unambiguous interpretation. In this research, two macro indicators of sustainability are assessed and empirically implemented with respect to Alberta’s forest industry and oil and gas industry. These are environmentally-adjusted gross domestic product (GDP), or “green” GDP, and the Pearce-Atkinson measure (PAM) of weak sustainability. This work applies two of these indicators of sustainability to Alberta for the period 1975 to 1995, focusing on the forestry and energy industries. Tamai MSc thesis research extends the green forest GDP accounting to the national level.

Time Preference and Tenure Rights

There are two major lines of research under this sub-project. The first focused on policy issues relating to time preference and attempted to answer the following question: What characteristics of forest management policy are preferred? This question was answered with respect to four different forest management attributes. The first is the public’s time preference or preference regarding the evenness of the flow of benefits. The second attribute explored relates to how individuals view the temporal ordering or sequencing of gains and losses with regards to timber and recreational benefits. The possible dependence of the individual discounting rates on the nature of the good (particularly, timber versus recreational benefits) or a “goods effect” was the third attribute explored in this study. The fourth attribute relates to uncertainty or variability in the flow of benefits. This study also explored how individual demographics influence choices regarding these attributes. The results offer insights into the public’s preferred order of characteristics for intertemporal forest management scenarios.

The second line of research under this sub-project related to the analysis of the effects of an allowable cut effect program. The ACE is a form of sustained yield policy that allows tenure holders who invest in certain silvicultural and management practices that increase future yields to be rewarded with an increase in their current annual allowable cut (AAC). The Alberta Forest Service is considering using the Allowable Cut Effect (ACE) program to encourage forest tenure holders to engage in effective forest management (EFM). This study derives theoretical estimates of the volume returns to ACE investments with varying constraints imposed on the forest. In addition, it explores the pragmatic question of the financial feasibility for tenure holders of adopting sustained yield programs such as ACE.

SUMMARY OF DATA ANALYSIS

Environmentally Sensitive Productivity Analysis

Pulp and paper industry

Data and analytical techniques

Industry aggregate time series data for the period from 1959 to 1994 was used. Each of these 36 observations includes data on four desirable outputs, two undesirable outputs and seven inputs. The marketable outputs identified in the study are wood pulp, newsprint, paper other than newsprint, and paperboards and building boards. Biological oxygen demand (BOD) and total suspended solids (TSS) are the two undesirable outputs included in the analysis. The seven input categories are energy, wood residue, pulpwood, non-wood materials, production labour input, administration workers, and capital. These data are described in more detail in Hailu (1998).

Input distance functions are used to model the production technology of the Canadian pulp and paper industry.[1] Input distance functions are capable of handling multi-output technologies and require only quantity data on inputs and outputs. The reciprocal of the input distance function value provides an input-based measure of technical efficiency. Input-based measures of technical change can also be easily obtained from the input distance function. The input-based Malmquist index of productivity change due to Caves, Christensen and Diewert (1982) is also defined in terms of input distance functions. The Malmquist index is used to summarize productivity growth trends in the Canadian pulp and paper industry over the period from 1959 to 1994. More details on the choice of techniques and productivity measures are provided in Hailu (1998) and Hailu and Veeman (2000).

For the case of a production technology using N inputs to produce M outputs, Shephard's (1953, 1970) input distance function can be defined as follows, after the introduction of a time trend in our particular case to capture technological change,

$$D(u,x,t) = \sup_q \{q : (u, \frac{x}{q}) \in Y(t), q \in R_+\} \qquad [1]$$

where: x and u are, respectively, the input and output vectors; t is the time trend variable; and Y(t) is the technology (or production possibility) set at time t. In other words, the value of the input distance function measures the maximum amount by which the input vector can be deflated, given the output vector. It measures the minimal proportional contraction of the input vector required to bring it to the frontier of the input requirement set for the output vector.

[1] The analysis of this industry was also conducted using nonparametric methods. To save space, we will limit our discussion to the input distance function modelling only in this report. The results from the nonparametric approach corroborate those obtained from the input distance function approach. More details about the nonparamteric analyses are available in Hailu (1998) or Hailu and Veeman (1998).

The input distance function is concave and homogeneous of degree one in inputs. We also distinguish between the derivative properties of the input distance function with respect to desirable and undesirable outputs. The input distance function is required to be non-increasing in desirable outputs but non-decreasing in inputs. The function is also required to be non-decreasing in undesirable outputs to take into account the costly nature of pollution abatement.

Once the representation of the technology is properly characterized to recognize that pollution abatement is costly, the environmentally sensitive input-based measures of productivity change are sensitive to changes in undesirable outputs and properly take into account the use of resources for pollution abatement purposes. See Hailu and Veeman (2000) for more details.

The input-based measure of technical change is defined as the rate at which inputs can be proportionally decreased over time with outputs held constant. This rate is computed as the derivative of the input distance function with respect to the time trend variable. To measure productivity change due to technical change and variations in the degree of technical efficiency, the Malmquist index due to Caves, Christensen and Diewert (1982) is used. The calculation of the growth rate in the Malmquist index was carried out using the following formula:

$$\begin{aligned} \ln M(x^{t+1}, x^{t}, u^{t+1}, u^{t}) = \{&\ln D(u^{t}, x^{t}, t) - \ln D(u^{t+1}, x^{t+1}, t+1)\} + \\ &\{TC_x(u^{t+1}, x^{t+1}, t+1) + TC_x(u^{t}, x^{t}, t)\}/2 \end{aligned} \qquad [2]$$

The first term in square brackets measures the rate of improvement in technical efficiency between period t and t+1. The second term represents the estimated rate of technical change over that period obtained by averaging the technical change growth rates for periods t and t+1.

Not only does the distance function approach not require external estimates of pollution damage values, but it can also be used to derive pollutant shadow prices that indicate the *marginal* costs of pollution abatement to the producer. These marginal abatement cost estimates are useful for further economic analysis and for guiding environmental policy. The marginal costs of pollution abatement are computed based on the producer marginal rate of transformation between pollution abatement and desirable outputs as calculated from the estimated input distance function.

The translog functional form is chosen for the input distance function and its parameters are estimated using mathematical (goal) programming. The estimation method relies on the minimization of the sum of deviations of the values of the function from the frontier that is being estimated, subject to the appropriate monotonicity, homogeneity and symmetry conditions. An additional constraint imposed for the estimation is the requirement that the value of the input distance should be equal to or greater than unity for all observed input-output combinations.

Productivity growth estimates

For comparison purposes, productivity growth estimates were computed with and without considering pollutant outputs. The results are discussed briefly below. More details on these are available in Hailu and Veeman (2000) or Hailu (1998).

When the conventional approach that ignores pollutant outputs or pollution abatement activities is followed, the results indicate that the average rate of productivity growth in the industry was only 0.19 percent per year over the 1959 to 1994 period. The estimates also indicate that most of this productivity growth occurred in the 1980s (0.99 percent per year) and the early 1990s (3.95 percent per year). The 1960s and the 1970s were marked by periods of productivity decline (-1.55 and –0.74 percent per year, respectively) according to the results from input distance function analysis without pollutant outputs.

Productivity growth estimates, however, change dramatically when pollutant outputs are incorporated into the analysis. The average annual growth rate of the Malmquist index obtained from the input distance function that includes undesirable outputs is 1.00 percent. This estimate is substantially higher than the rate of 0.19 percent calculated from the input distance function involving no pollutant outputs. The results also show that most of the productivity growth in the Canadian pulp and paper industry occurred in the period after 1982 and was fastest in the first half of the 1990s. Mean productivity growth estimates of –0.12, -0.32, 1.84 and 4.19 percent per year were obtained for the 1959-1969, 1970-79, 1980-89 and 1990-94 periods, respectively.

We observe differences between the conventional and the environmentally sensitive input-based estimates of productivity growth because the latter is sensitive to changes in pollutant outputs and credits the industry for pollution abatement activities while the conventional measure does not. The industry has been reducing its BOD and TSS outputs at average annual rates of 3.3 and 5.9 percent, respectively, between 1959 and 1994. See Figure 1. The conventional productivity measure, by neglecting these reductions, fails to indicate that a higher percentage of inputs could have been saved if there were no pollution abatement. The environmentally sensitive productivity measure, on the other hand, leads to higher productivity growth estimates for the industry because this measure is based on the measurement of the input savings that would be achieved if not only desirable outputs but also undesirable outputs were held constant. In other words, the environmentally sensitive productivity measure credits the industry, not only for its production of marketable outputs but also for its production of better environmental quality through pollution abatement. Thus the environmentally sensitive measure is a better indicator of true productivity growth and the contributions of the industry from the social point of view.

In sum, according to the conventional measure, the productivity of the Canadian pulp and paper industry increased by only 7 percent over the entire 36 year period from 1959 to 1994. By comparison, the results from the analysis with pollutant outputs indicate that the industry was

41.8 percent more productive in 1994 than it was in 1959. These productivity indexes are plotted in Figure 2.

The producer marginal cost of abatement for BOD were generally less than $100 for the first two decades covered in this study. The average shadow prices for the 1960s and the 1970s were very close. The prices for the 1980s and the 1990s are, however, much higher. The average BOD shadow price increases from $34 for the 1970s to $147 per metric tonne for the 1980s and to $436 per metric tonne for the period from 1990 to 1994. The average value of the BOD shadow prices for the period 1959 to 1994 is $123 per metric tonne.

The marginal abatement cost estimates for TSS were generally found to be higher than those obtained for BOD. For the period from 1959 to 1994, the average of the TSS shadow prices was calculated to be $286 per metric tonne. Like the BOD prices, the TSS prices show increasing trends over time. TSS shadow price estimates ranged between $100 and $300 during the 1960s and 1970s with average values of $161 and $157 per metric tonne, respectively. Average prices of $365 and $663 per metric tonne of TSS were calculated for the 1980 to 1989 and 1990 to 1994 periods, respectively.

Figure 1.
Biological Oxygen Demand (BOD) and Total Suspended Solids (TSS)
Production Rates: The Canadian Pulp and Paper Industry

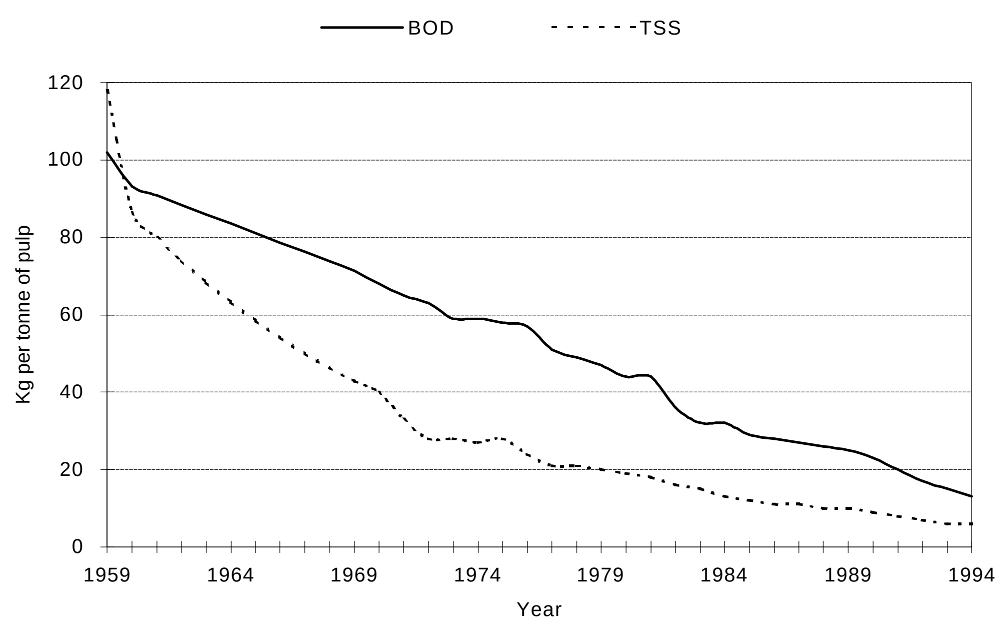
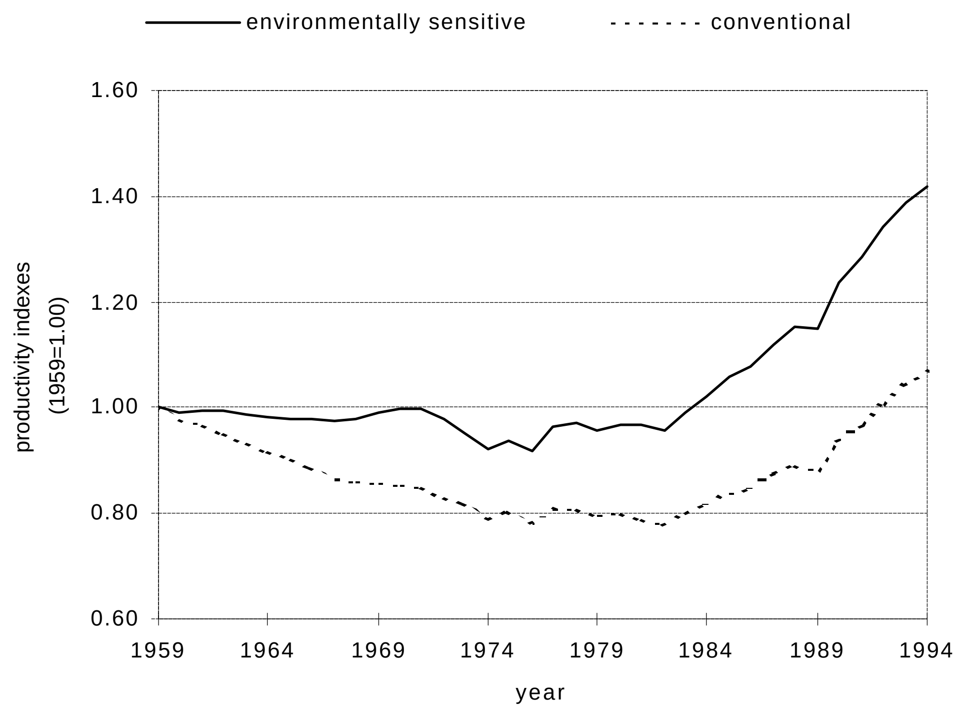


Figure 2.
Malmquist Productivity Indexes for the Canadian Pulp and Paper Industry, 1959-1994: Results from Input Distance Functions



Boreal logging industries

Data and analytical techniques

A panel data set covering the period from 1977 to 1995 and six regional boreal logging industries was used for this analysis. The regions or provinces included in the study are Newfoundland, Quebec, Ontario, Manitoba, Saskatchewan, and Alberta. Output is measured as total roundwood production, measured in thousands of cubic meters. Three capital and three other inputs are identified for the study. The three capital inputs are building construction capital, engineering construction capital and machinery and equipment capital. The three other inputs identified in the study are energy, operating and supplies expenses, and labour. In addition to conventional productivity growth estimates, the paper reports productivity change estimates that are adjusted to take the habitat and environmental effects of logging activities into account. Unlike in the case of the pulp and paper industry, the are no straightforward empirical measures that would allow us to capture some or all the environmental effects of logging. There is a need for measures or indexes that quantify and summarize the impact of logging on natural habitates, biodiversity, forest soil, aesthetic, etc. for monitoring and analysis at the industry or macro levels. The researchers in this project are currently involved in work on such indicators. In the meantime, the ratio of clearcut area to roundwood production is used in this study as a proxy variable for measuring these environmental effects as a first step towards more rigorous accounting of these effects in logging productivity research.

The production technology is modeled using a data analysis envelopment (DEA) model. To allow for the non-neutrality of technical progress, a recently proposed transitive measure of technical change is employed. A transitive measure of productivity change that combines technical progress and changes in the degree of productive efficiency is computed. A double-bounded Tobit model was then used to examine the effects of several region-specific variables on the degree of technical efficiency.

<u>Regional efficiency and productivity change: estimates and analysis</u>

The empirical investigation reveals that logging activities in the boreal industry are characterized by substantial and persistent efficiency differentials. In particular, the average annual financial loss due to technical inefficiency in the most important boreal logging regions, namely Quebec and Ontario, amounted to over $240 million per year for the period from 1977 to 1995. The average annual loss due to technical efficiency for all the six boreal regions was about $270 million per year. Newfoundland had the lowest level of technical efficiency, followed by Ontario, Quebec and Manitoba, all of which had average efficiency levels ranging from 81 to 89 percent. Alberta had the highest level of technical efficiency, with an average of 100 percent. Saskatchewan had the second highest efficiency score, at 95 percent.

The estimates from the Tobit analysis of efficiency differentials indicate that forest resource characteristics such as forest density (i.e. roundwood harvest per area) and proportion of hardwood production were found to have positive effects. There was also evidence of significant positive scale effects. Engineering construction per area, the share of logging in regional employment and regional cyclical factors were found to be negatively related to the degree of technical efficiency.

The overall rate of improvement in the degree of technical efficiency in the boreal region was slow, at an annual rate of 0.31 percent per year. Our estimates also indicate that the unit isoquant in the boreal forest harvesting industries shifted inwards at an average rate of 1.00 percent per year. As a result, total factor productivity in the boreal logging industry progressed at an average annual rate of 1.3 percent in the period from 1977 to 1995. However, when the productivity estimates are adjusted for environmental effects using the proxy variable mentioned above, technical change and total factor productivity estimates remain almost the same.

Macro-economic Sustainability Indicators

Current economic definitions of sustainable development tend to focus on non-declining well-being over time (Pearce, Barbier and Markandya, 1990). Several authors have identified a relationship between non-declining utility or well-being, and the underlying capital stock (Pearce and Atkinson, 1995). A well-established line of analysis has thus identified non-declining total capital stock, i.e. natural and man-made capital ($K_n + K_m$), as a key condition for sustainable development (human capital is not included, due to measurement problems). Further, Hartwick (1977) has shown that the relationship between non-declining well-being and non-declining total capital stock equates to a requirement to invest the Hotelling rents from natural resource use (Pearce and Atkinson, 1995).

Hartwick's rule, then, requires us to reinvest the Hotelling rents from natural resource extraction, in either man-made capital or new natural capital. It is assumed that natural capital may be substituted by man-made capital (see discussion below). Our empirical work for the province of Alberta implicitly involves two applications of Hartwick's rule, namely EDP and PAM, focusing on the forestry and energy industries during the period from 1975 to 1990.

EDP is a measure of environmentally adjusted GDP that takes into account not only man-made capital capital depreciation (σ_m) but also depreciation of natural resources and environmental assets (σ_n). That is, EDP is obtained from the conventional Net Domestic Product (NDP) measure by further subtracting the estimated value of natural resource depletion. If two economies have the same rate of growth of NDP, but one economy is depleting its natural capital at a lower rate, the EDP will reflect that the two economies are contributing differently to their future welfare. This calculation can be represented as:

$$EDP = GDP - \sigma_m - \sigma_n \qquad [3]$$

The second indicator of sustainability computed in this study is the Pearce-Atkinson Measurement (PAM). Simply, the PAM isolates the depreciation of capital from total growth. It is based on the premise that an economy is sustainable if savings (S) exceed the combined depreciation of man-made and natural capital ($\sigma_m + \sigma_n$). When PAM is positive, the economy is following a sustainable path. Numbers are divided by income in order to give a more accurate measurement, resulting in PAM_2. This calculation can be represented as:

$$PAM_2 = S/Y - \sigma_m/Y - \sigma_n/Y \qquad [4]$$

Both of these indicators are limited by some common parameters. The most important limitation is that both measurements relate only to weak sustainability. Accordingly, they both assume that man-made and human capital are completely substitutable. Many ecologists disagree with this assumption. If the assumption does not hold up, then depletion of natural resources and the environment cannot be compensated for with growth in physical capital. Accurate measurements of sustainability are thus no longer being obtained. Another limitation is that these indicators measure only depletion of nature, but not degradation. Hence, the value of timber extraction in forests is considered but not the viability of the forest as a wildlife habitat from such intrusions as roads.

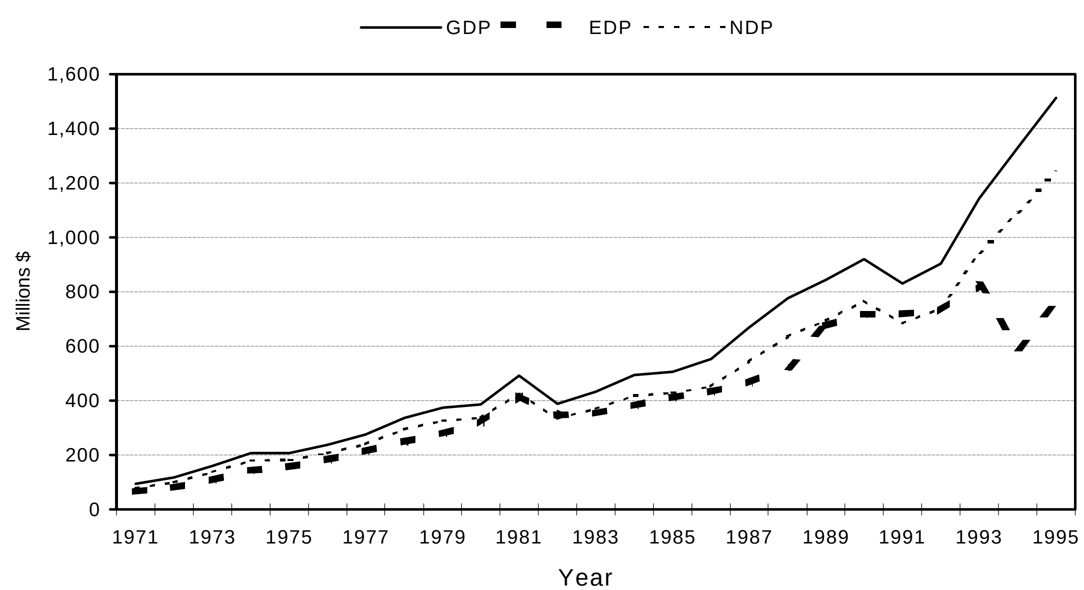
The results showed that generally, Alberta had experienced sustainable growth in the given time period. The "Green" GDP (EDP) for the forestry industry grew substantially. Another EDP was taken for the energy sector, which also grew over the 1975-1995 time period.

See Figure 3. Interestingly, levels of GDP and EDP differed by as much as 10% for both the forestry and energy sectors. The Pearce Atkinson Measurement indicator was usually greater than zero. Notably, more negative results occurred in the latter decade (1985-1995) than the earlier decade (1975-1985).

These two indicators demonstrate a generally sustainable path of development for Alberta, given their limitations. In the last 25 years, Alberta's decisions about usage of forests, oil and gas, have resulted in growth patterns that allow for consistent levels of usage in the future.

This work also neatly demonstrates how environmental sustainability can be clearly and unambiguously incorporated with traditional measures of economic growth, such as GDP. Efforts should be made to increase data available on depreciation of environmental resources such that "Green" GDP and Pearce Atkinson Measurements are more comprehensive and have more information to be compared with. As well, efforts should be made to develop "strong sustainability" indicators, i.e. indicators that take into account substitutability of natural and man-made capital in a relatively unambiguous way. See Pearson and Veeman (1999) for additional details.

Figure 3.
Alberta Forest Industries: GDP, NDP, EDP (Millions $)



Time Preference and Tenure Rights

In Taylor's (1999) analysis of policy issues relating to time preference, simulated forest management scenarios were developed that demonstrated combinations of the four tested characteristics, namely time preference, the ordering of gains and losses, the goods effect, and uncertainty. The impact of individual demographics on choice was also explored. Questions were created that asked interviewees to choose between a series of two scenes presented in graph format (a discrete choice questionnaire). Each scenario, describing a 100-year time frame, involved two goods, timber and recreational use. The surveys also included questions on individual demography.

Surveys were distributed to Public Advisory Councils across Alberta, eight of which responded. PAC's were chosen because they were accessible. As well, the people on the committees, consulting bodies for Alberta Forest Management Agreements, were familiar with the forest industry. From these select interviewees, results were to be extrapolated onto society at large.

With respect to time preference, the results demonstrated that individuals favoured forest management scenarios that produced a stable flow of benefits over the 100-year time frame. Given the two scenarios, respondents preferred scenarios with flat time paths over scenarios that were characterized by large variation from a constant time path. With respect to gains and losses, scenarios with losses ahead of gains were preferred over scenarios with gains ahead of losses. With respect to variation, respondents preferred scenarios with lower (5%) variance bounds than with higher (10%) variance bounds. The results also suggest a goods effect, in that different discount rate preferences were observed for timber and recreation.

Based on these results, future forest management policies that attempt to accommodate public concerns should consider these preferred characteristics. Plans should emphasize a stable forest management plan, inclusive of a variety of forest usages, that stress gains in the future over gains today followed by future losses. See Taylor (1999) for more details.

Hegan and Luckert's (2000) work on forest tenure rights derives theoretical estimates of the volume returns to ACE investments with varying constraints imposed on the forest. In addition, the paper explores the pragmatic question of the financial feasibility for tenure holders of adopting sustained yield programs such as ACE.

To test the effectiveness of ACE in changing harvest volumes, a set of timber supply models were constructed. Each model went through 200 time periods, representing years, under varying constraints. These constraints included the age distribution of the initial forest inventory (juvenile, mature); the species composition of the annual allowable cut (coniferous/deciduous); the type of effective forest management investment (intensive/extensive), and the harvesting flexibility around the annual allowable cut.

The results show that positive ACE volumes occur only with restricted circumstances. If the initial forest structures are dominated by juvenile trees, then ACE volumes are neutral or negative. If initial forest structures are dominated by mature trees, and if both deciduous and coniferous volumes are included in calculations, then ACE volumes are positive or negative. If initial forest structures are dominated by mature trees, and only coniferous volumes are accounted for, then and only then are ACE volumes consistently positive.

Obtaining positive ACE volumes is a necessary but not sufficient condition for the ACE program to entice tenure holders to participate; it should also be viewed as a positive financial investment. To determine the economic criteria pursuing an investment, net present values are taken into account for the potential ACE investments, at a discount rate of 2% and with moderate stumpage fees. The only positive net returns occur when the initial forest is mature and only coniferous volumes are counted. Within this situation, returns are higher with extensive rather than intensive investments. Even with these given circumstances, it is uncertain whether it would be in society's best interest for an investment to be pursued. Deciduous volumes are ignored in these calculations, and adverse effects on hardwood trees may be overlooked.

This report brings considerable doubt to future policy makers of the efficacy of adopting the ACE program. Using a 200-year model, only in restricted circumstances do ACE investments make sense in terms of increasing forest volumes and producing a positive financial return. It brings doubt as to whether forest companies in Alberta would be willing to adopt the program, and whether the adoption of the plan is in society's best interests. Additional details are provided in Hegan and Luckert (2000).

MANAGEMENT APPLICATIONS

Environmentally Sensitive Productivity Analysis

Productivity growth is crucial for the maintenance of the position of the Canadian forest sector in the world market and for the ability of this sector to continue to make its significant contributions to the national economy. This study employed techniques that allow researcher managers, investors, company leaders and policy makers to gauge the performance of the forest industries more accurately. The following important policy and management implications are drawn from the results of the productivity studies reported above.

1) The results and implications of conventional measures of productivity growth need to be interpreted with caution. By ignoring the environmental contributions of pollution abatement activities in the Canadian pulp and paper industry, these estimates have underestimated true productivity growth in that industry and thus the benefits of additional R & D or additional capital investment in the industry.

2) The increasing trends in the marginal producer cost of pollution abatement for the two traditional water pollutants (BOD and TSS) indicates the need for a search of more cost efficient environmental or regulatory instruments. It also indicates the need for enhanced investment in the search for improved pollution abatement technologies for the Canadian pulp and paper industry.

3) The persistence of significant efficiency differentials among the boreal logging regions points to the importance of the consideration of regional factors in the design of policies aimed at regulating these industries. The evidence indicates that technical efficiency is positively correlated with scale of production and forest stand characteristics such as density and share of hardwood harvested.

4) There was no evidence of significant improvement in the estimated boreal productivity growth rates when environmental effects are incorporated into the analysis using the proxy clearcut/production ratio variable. Although the variable used to capture environmental effects of forest harvesting is a crude one, it does serve as a rough measure of changes in forest harvesting regimes. Therefore, the absence of any superiority in the environmentally sensitive measure over the conventional one is cause for concern. What does this finding indicate? Does it indicate the weakness of the environmental effect proxy variable that has been used here? Or does it indicate that the industry is only experimenting with new forest harvesting regimes or that these new approaches would have to be greatly expanded before we could see significant changes at the regional or aggregate levels? These are important questions that call for a closer examination of the response of the forest logging industry to public environmental concerns over the last few decades.

Macro-economic Sustainability Indicators

1) As with the environmentally sensitive productivity analysis, this study demonstrates that conventional growth measures should be interpreted with caution. It is clear that depreciation of man-made capital detracts from real growth. With natural capital, measurable only in uncertain and indirect terms, this depreciation is somewhat less obvious. Yet declines in stock of forests, as well as oil and natural gas reserves, have an impact on what can be produced in the future equal in significance to declines in man-made capital. Environmentally adjusted NDP offer a comprehensive and clear measurement of depreciation in natural capital.

2) Alberta’s growth in the decade 1985 to 1995 shows a decrease in years of sustainable growth over the previous decade. This suggests closer attention should be paid towards environmental resource depletion in the province. Policies and regulations from both the public and private sector should reflect a realization that natural capital depletion needs to be substituted with adequate environmental or man-made capital creation.

3) Further research needs to be done to determine the degree of capital substitutability in the circumstances of Alberta. Capital stock contributes to future production. It is yet to be determined whether a decline in man-made capital stock is truly comparable to a depletion of oil reserves or forest lands in restricting future production. A risk exists that there is a critical minimum level of forestland or mineral reserves that once reached, cannot be built up from, thus permanently limiting the extent of natural capital in the province. If such a level exists, it is crucial it is discovered before resource depletion meets it.

Time Preference and Tenure Rights

1) The time preference work undertaken by Taylor indicates the presence of a public preference in Alberta forest communities for a stable flow of benefits over forest planning scenarios, as well as the presence of different time preference rates for timber versus recreational use. Based on these results, future forest management policies that attempt to accommodate public concerns should consider these preferred characteristics. Plans should emphasize a stable forest management plan, inclusive of a variety of forest usages, that stress gains in the future over gains today followed by future losses.

2) The work on forest tenure rights tells us that there are several points that stakeholders need to note.

    a) Even before consideration of the type of sustained yield program adopted, the entire paradigm of sustained yield forestry management needs to be brought into question. In recent decades, governments have been eager to adopt forestry management regimes with smooth flow harvest, such as ACE, without sometimes considering the full costs and benefits of the program. Yet economists have long considered sustained yield a dubious policy guideline on a variety or fronts. Amongst the various concerns, the policy does not allow for non-timber usages of the forest. As well, it does not allow for flexibility in harvesting according to market conditions. Serious evaluation must be given as to what the goals of forestry management are before policies relating to one paradigm, sustained yield, are imposed.

    b) Given that sustained yield is a desirable goal, the allowable cut effect program must be considered for its potential to achieve SY goals.

        i) Some factors that have appeared to impede the success of the program can be altered by an adjustment in government policy. For instance, the collection of stumpage fees on the enlarged annual allowable cut could be removed. As well, AAC rights could be more firmly secured, and extra AAC volumes confirmed, so that investors enter into the program with more certainty. Finally, other programs that inadvertently compete with the ACE program to encourage silviculture, such as reimbursement programs or requirements, exhaust invest opportunities, leaving little for ACE to stimulate. These programs could be streamlined to allow for a more efficient application of the ACE investment program.

ii) Some factors are more difficult to be resolved by policy adjustments and demand a reevaluation of ACE as a policy mechanism for achieving sustained yield. For example, some investors do not use the extra annual allowable cut granted to them, undermining the purpose of the policy.

CONCLUSIONS

The research components of this project have explored different issues related to the sustainable management of Canadian forests. Hailu's work focused on the analysis of productivity trends in the forest sector both in conventional and environmentally-adjusted ways. The macro level sustainability of Alberta's economy was the focus of the research by Pearson. Taylor and Hegan and Luckert explored policy issues relating to time preference and forest tenure rights.

Hailu has analyzed productivity trends in the Canadian pulp and paper and the boreal logging industries. These analyses were done in ways that account not only for marketed inputs and outputs but also for changes in the environmental effects of these industries. Adjustments for environmental effects are especially important in the case of resource based industries such as the Canadian pulp and paper and logging industries.

The productivity and efficiency estimates were generated using input distance function analysis in the case of the pulp and paper industry and through the use of data envelopment (DEA) analysis for the boreal logging industries. The pulp and paper industry uses national industry time series data covering the period from 1959 to 1994 and generates both conventional and environmentally sensitive estimates of productivity change. The logging study is based on panel data set covering the period from 1977 to 1995 for six boreal logging regions, namely, Newfoundland, Quebec, Ontario, Manitoba, Saskatchewan and Alberta.

The empirical results for the pulp and paper indicate that conventional measures that ignore the environmental benefits of the industry's pollution abatement activities understate the true productivity growth that occurred in the industry over the 36 year period covered in the study. When measured in ways that take the environmental benefits of pollution control into account, it was estimated that the average annual rate of productivity growth for the industry was 1.00%, higher than the conventional estimate (of 0.19%) obtained from the same data set or the estimates obtained for the same industry by previous studies.[2] R & D research expenditure managers, industry leaders and investors need to be aware of the extent to which traditional estimates of productivity growth can distort our understanding of the performance of industries that invest heavily in pollution abatement activities. The empirical results also indicate that the producer marginal costs of pollution abatement for the two traditional water pollutants of BOD and TSS from the pulp and paper industry have been rising steadily over the years, suggesting

[2] See, for example, Sherif (1983), Martinello (1985) and Frank et al. (1990).

the need for more efficient environmental protection or regulatory instruments as well as for investment in the search for improved pollution abatement technologies.

The investigation into the trends and determinants of productive performance in the boreal logging industries also revealed several interesting points. First, the empirical evidence indicates the presence of substantial differences in the levels of technical efficiencies across the provinces. Technical efficiency in forest harvesting is positively correlated with forest density, the proportion of hardwood harvested from the forest and the scale of production. The intensity of engineering construction capital, relative to area harvested, was found to be negatively correlated with the degree of productive efficiency. While the rate of improvement in technical efficiency progressed at an average annual rate of 0.31 percent, the rate of technological progress in boreal forest harvesting was estimated to be 1.00 percent per year, thus resulting in a combined productivity growth estimate of 1.3 percent per year for industry. There was, however, no evidence of superior environmentally adjusted growth estimates. This absence of strong positive overall trends in forest harvesting regimes despite the growing public concern regarding forest management in the last three decades calls for a closer examination.

The study focusing on green accounting at the macro level has empirically implemented two indicators of sustainability with respect to Alberta’s forest and oil and gas industries. These are environmentally-adjusted gross domestic product (GDP), or “green” GDP, and the Pearce-Atkinson measure (PAM) of weak sustainability. Both indicators generally point to a sustainable path for Alberta’s economy, for the period studied. “Green” GDP, for the forest industry and for the province, shows overall increases from 1971 to 1995. GDP adjustments for timber and energy depletions are found to be as high as 10% of provincial GDP at certain points in time, in spite of steady progress in the discovery of new oil and gas reserves. The GDP adjustments for harvested timber have risen, in the 1990s, to about 10% of the adjustments for net oil and gas depletions. The PAM indicator is generally greater than zero from 1976 to 1995, although lower during the second half of that time period.

The research on time preference explored individual choices regarding stability of forest utilization, time ordering of gains and losses, discount rate choices for timber versus recreational benefits as well as uncertainty. Data for this research was collected using a survey of Public Advisory Councils in Alberta based on a questionnaire that depicted forest use scenarios over a 100-year time frame. The study also explored the impact of individual socioeconomic characteristics on preferences. The results from this study revealed several interesting points that should be taken into account in the design of forest management policies. First, a stable or ‘flatter’ spread of benefits was preferred to scenarios that involved large variations from a constant time path. Second, there is evidence of a preference for a sequence of flows with losses ahead of gains rather than vice-versa. Third, resource benefit flows with lower variability were found to be preferable. Finally, there is also evidence of a goods effect in that different discount rate preferences were observed with regards to alternative relating to timber as opposed to recreational benefits.

Hegan and Luckert's work on forest tenures examined the potential effects of the allowable cut effect (ACE) mechanism that is currently being considered by forest policymakers in Canada. A timber supply model was used to optimize harvesting schedules to maximize net present values over a 200-year planning horizon. A number of scenarios are investigated with variations in intensity of silivicultural investments, beginning age-class distributions, levels of flexibility around the allowable annual cut (AAC), calculations of AACs based on coniferous and mixedwood volumes, and green-up constraints. The simulations indicate that positive returns to ACE occurred only when operating under harvesting constraints with a mature starting forest and AAC calculations that ignored deciduous volumes. And in those cases where there were positive returns to the ACE, returns were higher for extensive, rather than intensive investments. Combining these results with other potential impediments to the ACE, previously identified in the literature, the researchers conclude that the probability of tenure holders having incentives to undertake ACE investments is low.

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